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TELEPHONES

AND

LIGHTNING CONDUCTORS

BY UMBERTO ZEDA

TRANSLATED FROM THE ORIGINAL ITALIAN AND REVISED

BY

S. R. BOTTONE

AUTHOR OF "IGNITION DEVICES," "AMATEUR ELECTRICIAN'S WORKSHOP," "TALKING MACHINES & RECORDS," "ELECTRICAL ENGINEERING FOR STUDENTS," "MODERN DYNAMOS & BATTERIES," ETC., ETC.

(AUTHORIZED EDITION)

SIXTY ILLUSTRATIONS

GUILBERT PITMAN

85 FLEET STREET, LONDON, E.C.

1907

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CHAPTER I.

Household Telephones.

IN the following pages we do not propose to give any lengthened description of the history of the telephone, but, after having briefly described the essential portions and their mode of action, we shall pass at once to give details as to the manner of erection — for the several purposes of household, office, and similar work; reserving for the next chapter the task of instructing the learner in the erection and management of long-distance telephones.

The modern telephone consists essentially in three parts—the transmitter, the line, and the receiver. Originally the transmitter and the receiver were made exactly the same, and they consisted in a cylindrical bar-magnet of about $\frac{3}{8}$ in. in diameter, and 4 ins. in length, encased in a wooden handle near to the extremity of the magnet, and fitted with an adjusting screw at the opposite end, by means of which the amount to which the free end of the magnet protruded from the handle could be regulated. On the other end of the magnet was fitted a bobbin wound with about sixty feet of fine insulated copper wire, the extremities of which were carried, one to each terminal of a circular wooden box of about $2\frac{1}{2}$ ins. in diameter, fitting over and attached to the case containing the magnet. The edges of this box were adjusted so that the protruding end of the

magnet was just flush with them. This box was itself fitted with a cover having a hole about $1\frac{1}{2}$ ins. in diameter cut out of its centre, to which was fitted a small mouthpiece, as in ordinary speaking-tubes. Before closing this cover or lid on the box, a thin disc of "ferrotype," fitting truly in its inside and separated from actual contact either with the lid or the box itself by means of narrow india-rubber rings, was placed therein; the cover was then fastened down and the magnet adjusted by means of the adjusting screw until it just cleared the "ferrotype" plate. The two instruments were then connected up at any reasonable distance by means of two insulated wires, precisely as a bell and battery.

On speaking into the mouthpiece of the one instrument, the vibrations set up by the voice caused the "ferrotype" plate thereof to vibrate; and in obedience to a well-known effect in electrical magnetism, the motion of the iron in front of the lines of force of the magnet set up currents varying in intensity and in amplitude in proportion to the intensity and amplitude of the vibratory motion of the "ferrotype" disc itself. Now, these currents were transmitted along the line wire, and, provided the distance did not exceed the carrying power of the instrument (say four to five hundred yards), a hearer at the other instrument would hear the word spoken, since the currents received by this instrument would affect its magnet, either by weakening or strengthening it, and thus altering its pull on its "ferrotype" disc, which consequently would enter into vibration and thus reproduce the sounds. But this form laboured under several disadvantages. In the first

place, it was not possible to transmit to any very great distance; secondly, the use of a separate bell (and often line wire) was necessary in order to call attention.

In the modern forms, the transmitter consists in a vibrating diaphragm, either of ferrotype or of very thin wood, behind which, in a suitable box or case, is arranged carbon granules, carbon pencils, or some other form of loose and easily disturbed contacts, in connection with a back metallic plate. The vibrating diaphragm and the back plate communicate electrically with one another through the loose particles or pencils of carbon only. Now, as the conductivity of carbon varies with the pressure, if such an instrument be placed in circuit with a battery and a telephone, such as that just described, any variation in the pressure on the carbon, due to vibration set up in the ferrotype diaphragm, would produce corresponding variations in the amount of current sent on to the receiving telephone, with the result that its diaphragm will enter into vibrations corresponding to those imparted at the speaker's end. Such a transmitter is known as a "microphone." The microphone is a great improvement upon the old magnet telephone, as the transmitter; but its efficiency is largely increased by connecting up with it a device known as the induction coil. This consists in a small reel or bobbin with a soft iron core, around which are wound two distinct layers of wire—the first, or "primary," consisting of a few turns of, comparatively speaking, coarse wire; the second, which is wound over the first, consisting of a large number of much finer wire. If the primary of this coil be placed in

circuit with a battery and microphone, on speaking into the diaphragm of the microphone, the vibrations set up produce, as we have said, corresponding variations in the strength and quantity of current passing through the primary; and these variations in current set up in the secondary wire similar variations, which, however, are magnified in intensity in the same proportion that the turns in the secondary bear to the turns in the primary; and, if the secondary wires are connected through the line wires to the receiver, its diaphragm is thrown into vibration, thus reproducing

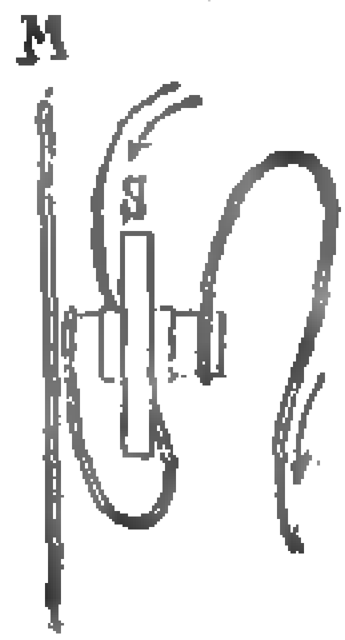

FIG. 1.

the sounds with much greater intensity and clearness than would result if the induction coil were not employed.

A good microphone can be employed without a coil to distances up to about three miles; but for long-distance work the coil is a great advantage. We will illustrate one of the less-known microphones in order to show the principle on which the instruments work. For example, in Mildé's microphone, Fig. 1, we have two short carbon cylinders, enclosed in the centre of a little metallic box, S, from which

they are, however, insulated by *means of a roll of* paraffined paper. The box itself is partially filled *with granules of graphite* (gas carbon). One of the carbon rods is glued to the centre of a very thin wooden diaphragm, M, and both are placed in communication with the external circuit by means of flexible wires, as shown by the arrows. Owing to the poor contact between the particles of the carbon, when the microphone is at rest, a very minute current only passes; but when speech is carried on *before the* diaphragm, the vibrations in the air, set up by the *vocal organs, cause the latter* to *vibrate*, and with it, the carbon rod attached. As a consequence of the force of inertia, the back portion of the containing case vibrates with less force than the diaphragm; hence follows a kind of compression in the little box, S, which is exerted on the carbon granules, accompanied by diminution in resistance. Owing to this, a larger current passes at these times, and the *receiver* therefore, draws more strongly the diaphragm facing *the pole of the magnet*. According to the rate and intensity at which these vibrations are set up, so the quantity of current and the rate of its undulations will vary. And since these variations in the intensity of the current are synchronous with the variations in pitch and intensity of the speaker's voice, it follows that the diaphragm of the receiving telephone will vibrate in accordance *with the vocal* chords; thus giving rise to sonorous waves which *reproduce faithfully those* emitted before the diaphragm of the transmitter.

We need hardly dilate on the many forms that are given to the arrangement of these parts, which go

under the generic name of "telephone." Some of these are semi-portable, and are constructed so as to be readily removed from one table to another. Others again are practically fixtures, and are attached rigidly to a wall or any support. To the former class the shape generally given is that of a watch-stand, in which the receiver hangs in position over the front of the mouthpiece of the transmitter. In

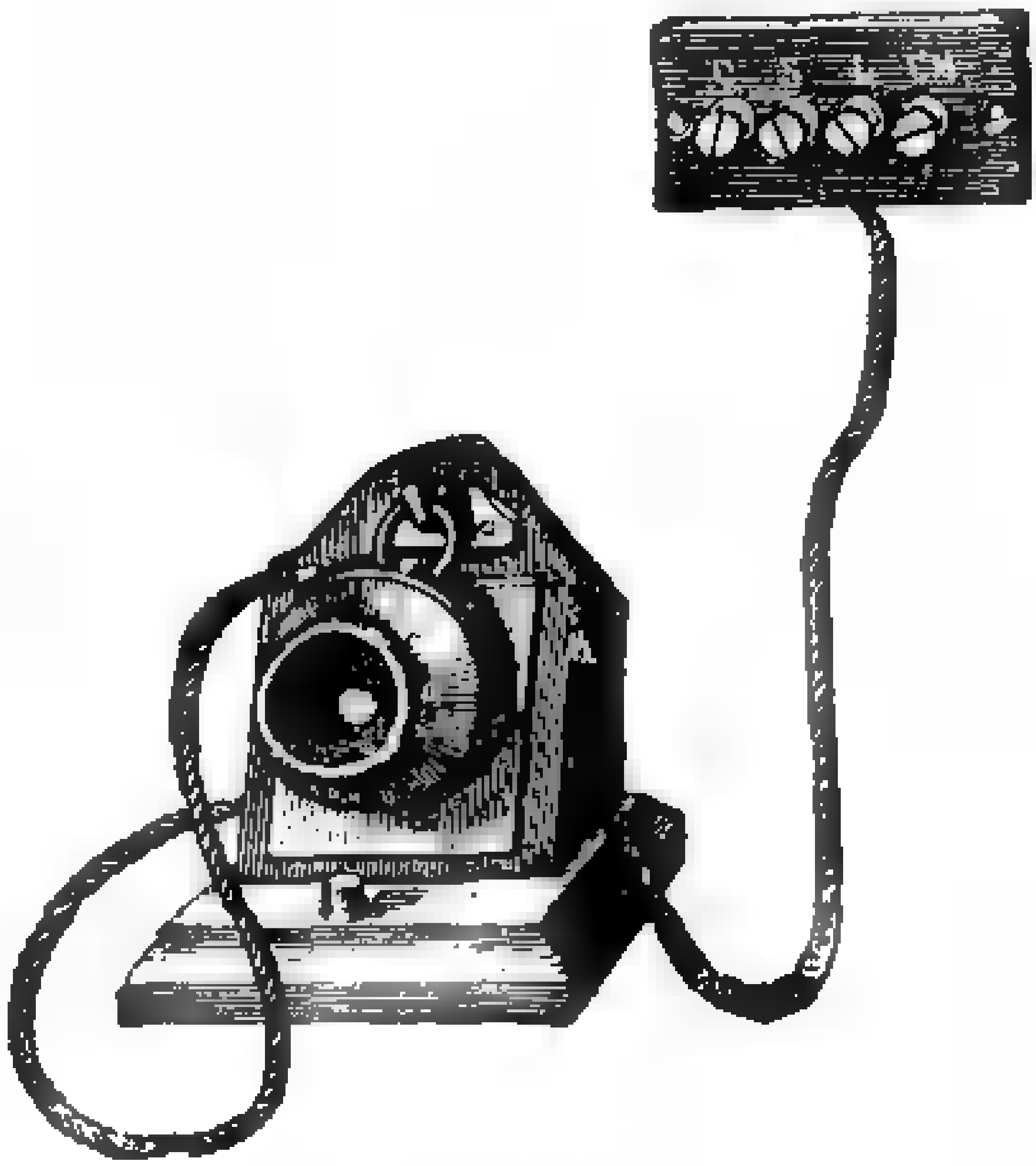

FIG. 2.

this case, the receiver itself is made in the shape of a watch, and the magnet, instead of being a straight bar, is bent into an almost complete circle, the two bobbins being brought to the centre of the diaphragm (ferrotype), and enclosed in a metallic case resembling a watch, but having the mouthpiece where the dial generally is. These two portions are connected together with the line wire and earth by means of twin flexible cord, as shown in Fig 2.

As it is necessary to be able to give notice to the hearer of the speaker's desire to send a message, it is essential to be able to call attention by ringing a bell situate in the correspondent's room or house; and this is effected by throwing the telephone or receiver out of circuit, and using the line wire for the transmission of the current necessary to ring the bell, without the employment of a separate line wire for the bell circuit. This, though apparently a difficult operation, necessitating the movement of the switch or switches, is easily effected almost automatically. Since, if the hook on which the receiving telephone hangs (when not in use) consists itself in a pivoted lever bearing at its farther extremity two separate contact pieces, one above and one below, it is evident that when the telephone is hanging on its hook, and therefore not acting as a receiver, its upper contact may be caused to place the bell only in circuit; while, directly the hook is released from the weight of the telephone (as would be the case when the receiving telephone is placed against the listener's ear to receive a message), that the bell would be cut out of circuit, while the receiver would be placed in circuit and be in a position to receive the message sent. The push, by means of which the bell is rung when the receiver is hanging on its hook, is shown in the centre of the baseboard in Fig. 2; above is seen a board carrying the connections to line, etc. Four terminals will be noticed, marked respectively C, S, L, and CM. These letters sometimes vary with the maker of the telephone, but their position is invariable—C being taken to the carbon of the battery, B going to the bell, L to the line, and CM to the

microphone. For short distances, where the battery power required to ring the bell is small, the two positive terminals are generally connected together, as may be gathered from the plans given later on. If, however, the telephones are working through at great distances, in which case heavier currents are required—which would be injurious to the working of microphones which take but little current—the

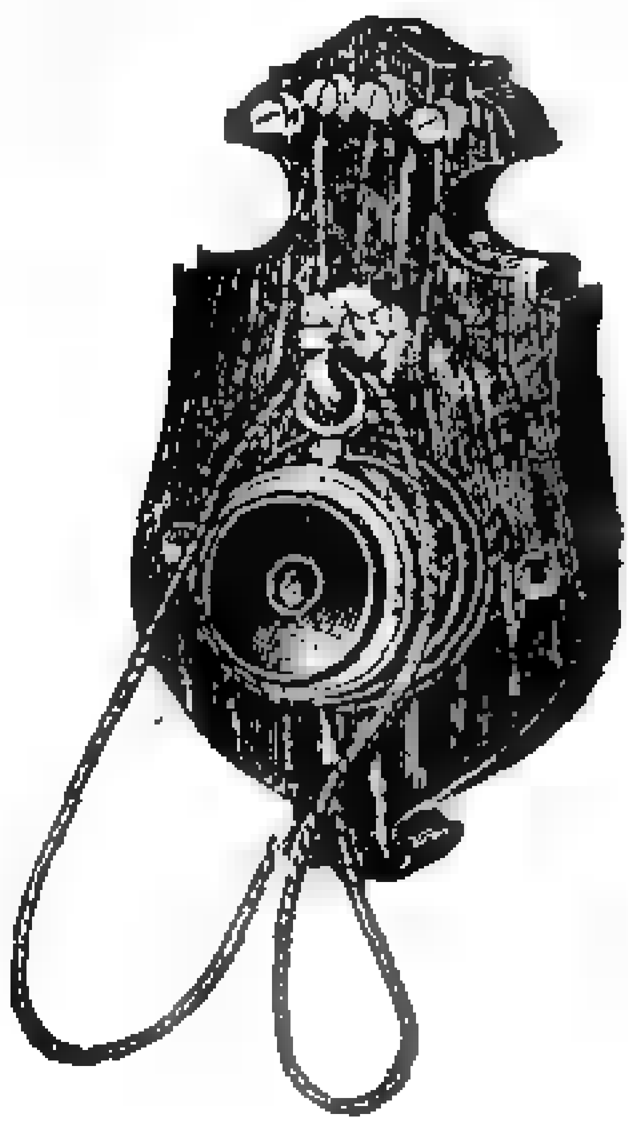

FIG. 3.

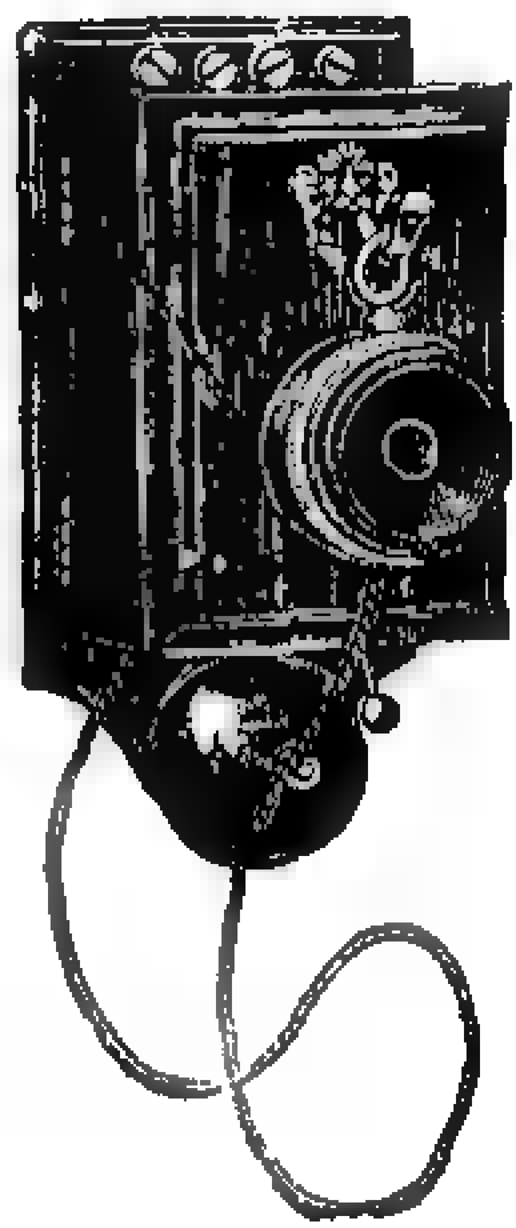

FIG. 4.

carbon microphone is coupled up to one of the carbons of the battery, which is thus split, so that the microphone receives the current of two or three cells only. A rather artistic form of the hook which serves as an automatic switch is shown in Fig 5, the back contacts of which will be illustrated later on. The mode of suspension of the watch form of receiver, by the hook, is shown to the left of our illustration at Fig 6. As before explained, the scope of the hook

(which by means of a spring rises upwards when relieved from the weight of the receiver) is to put the bell in circuit with the battery, while the receiver is hanging on the hook, and to throw the line in circuit with the battery microphone and receiver, when this latter is removed from the hook.

Of other types of telephones, we have those which

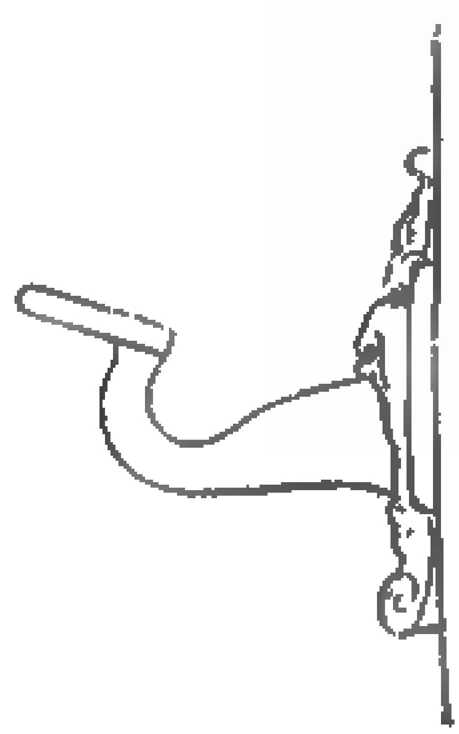

FIG. 5.

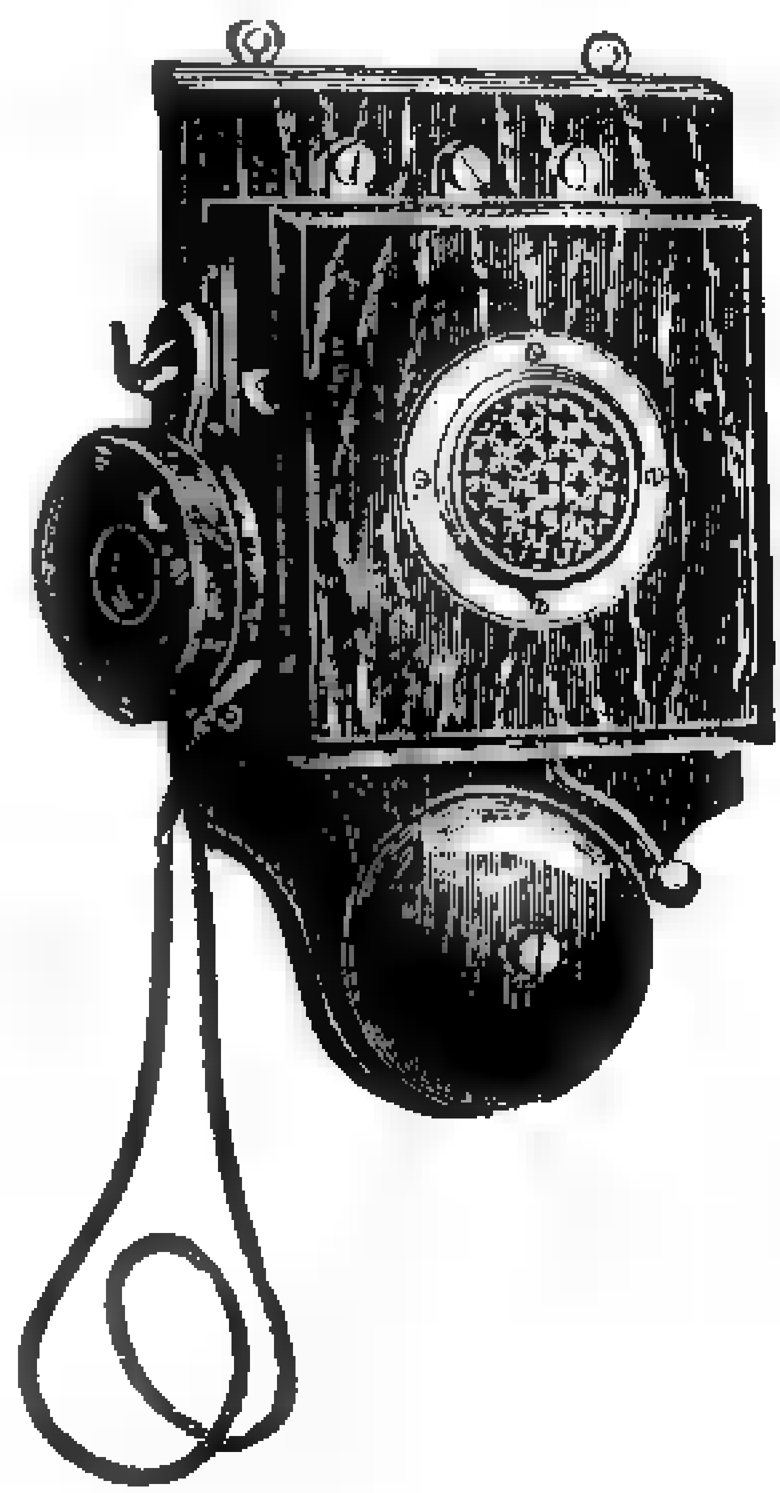

FIG. 6

are fixtures or partial fixtures, as in Figs. 3 and 4. In this latter, as also in Fig 6, we have bells of the heavier type, which naturally can be heard to greater distances. Again, in some of these telephones, the hook, besides acting as a switch, may also be arranged to take the place of the push. For instance, when

the receiver is hanging on its hook (that is to say, when the telephone is not being used), the bell circuit is closed. On pressing the hook downwards until it would go no farther, the circuit is closed on the bell of the distant telephone. When the receiver

FIG. 7.

is lifted off the hook, the microphone circuits are closed, and conversation may be effected. There are many other types of what we may call Household Telephones to be found in the market, which satisfy every requirement, and among these that known as

the "Berliner" is worthy of mention, both for its moderate price and for its satisfactory working. This is illustrated in Fig. 6. In these telephones there are usually only three terminals, namely, carbon, line, and zinc, so that it is not necessary to

FIG. 8.

FIG. 9.

have a large number of battery cells on to ensure clear transmission with a natural tone of voice. In these telephones the microphone consists of a thin sheet carbon diaphragm, protected by a strong metallic network. They are furnished with an

automatic switch hook (on the left) and a call-push on the opposite side. Another type of telephone is that shown at Fig. 7. In this the arrangement of the terminals is as follows:—Carbon, Bell, Microphone, Zinc, and Line. By uniting the two first together they can be worked for short distances with a small battery power. For short distances and for domestic use, as, for instance, to be rung on existing bell circuits from dining-room to kitchen, etc., the pretty little devices (Figs. 8 and 9) have come largely into use. These go by various names, but are usually known as *hand* combinations. In these, the line is thrown into circuit either with the bell or the microphone and receiver, by pressing the spring, which is shown to the left of Fig. 8 and to the right of Fig. 9. The internal construction of the parts is precisely similar to that of those previously described.

We can now pass to the consideration of the best modes of installing household telephones. A few words as to the choice of the places which they should occupy and the proper run of the lines will not be out of place here, since it is an important matter, and may influence largely the durability and the satisfactory working of the instruments. All micro-telephonic stations should be fixed to rigid supports; light partitions are to be avoided, since their vibration would be detrimental to the clear transmission of sounds, by entering into vibrations themselves, and thus confusing the proper reproduction of speech. Damp walls are also to be carefully avoided, because they favour the oxidization of the metallic portions, which may culminate in a break in the internal circuits, due to the wires being eaten

through. When it is absolutely necessary to place an instrument in a damp position, the precaution must be taken to detach it somewhat from the wall, by means of glazed earthenware or ebonite insulators. On the other hand, no micro-telephonic instrument should be placed near stoves, large fires, or anything which gives out much heat, because in this case the wood-work of the instrument getting too dry might upset the microphone and loosen the screws by which the connecting wires are held. As far as possible,

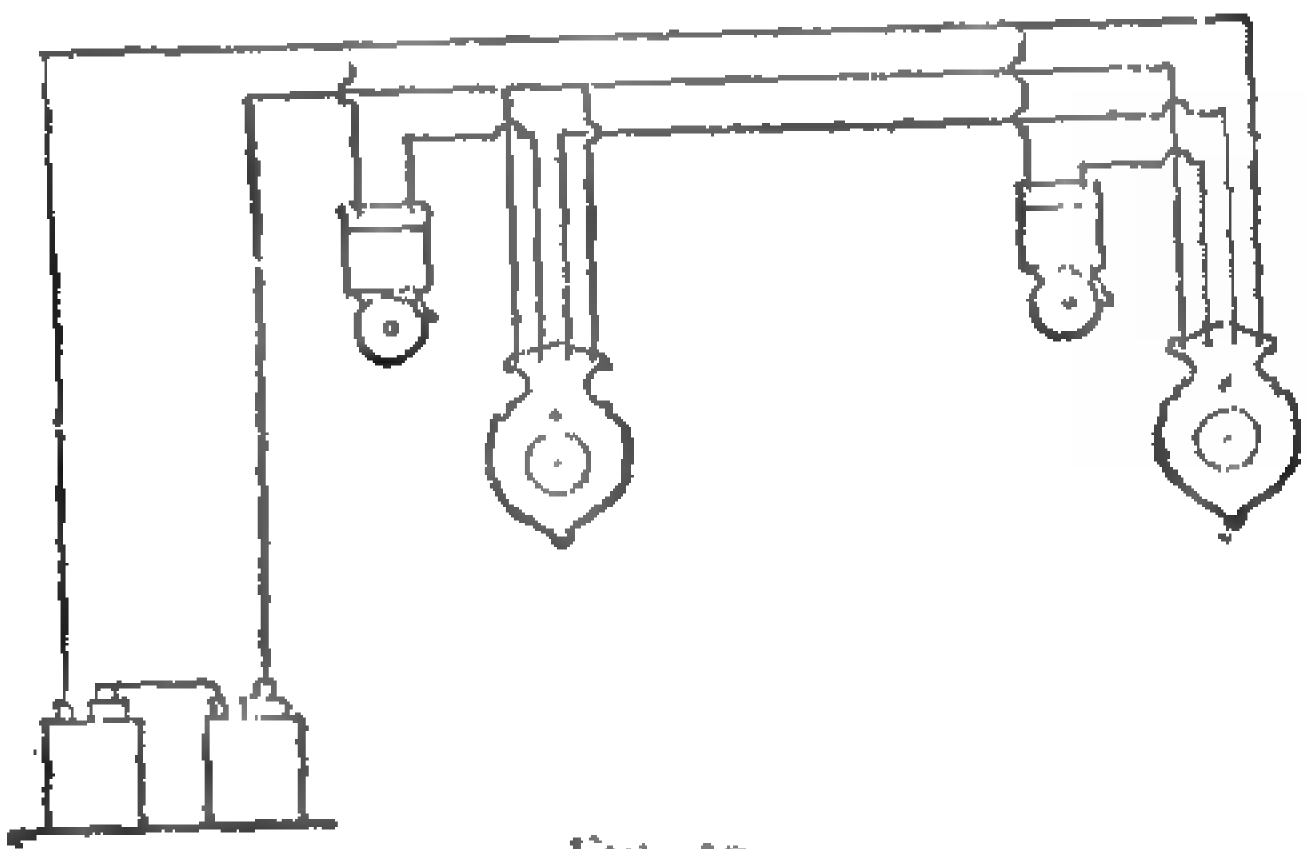

FIG. 10.

such instruments must be carefully protected from dust, which, by penetrating into the interior and becoming deposited on the moveable contacts, would probably interrupt the communication. In other regards, the installation should be carried out to the same rules that we have given in a previous work on bells,* with even greater attention to the careful insulation of the wires.

* "Electric Bells, Indicators, and Aerial Lines." By Umberto Zeda. Translated from the original Italian and revised by S. R. Bottone. 128 crown 8vo pages; 109 illustrations. Cloth, 2s. net.

By careful attention to the plans given herein, successful results can be obtained with certainty. At Figs. 10 and 11 we give the connections required

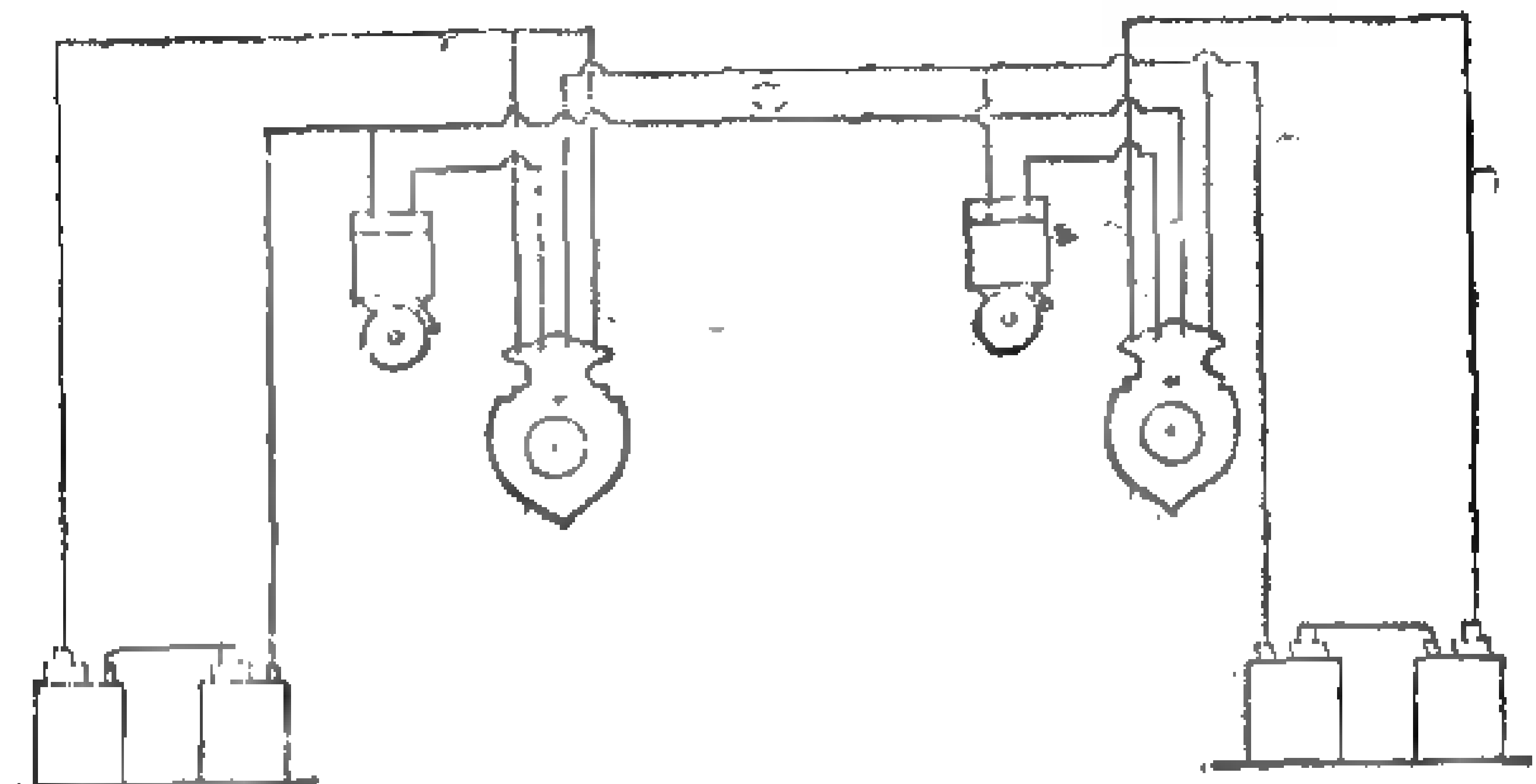

FIG. 11.

for two telephones with separate bells, and either with one or with two batteries. (In these plans we are referring specially to the four-terminal

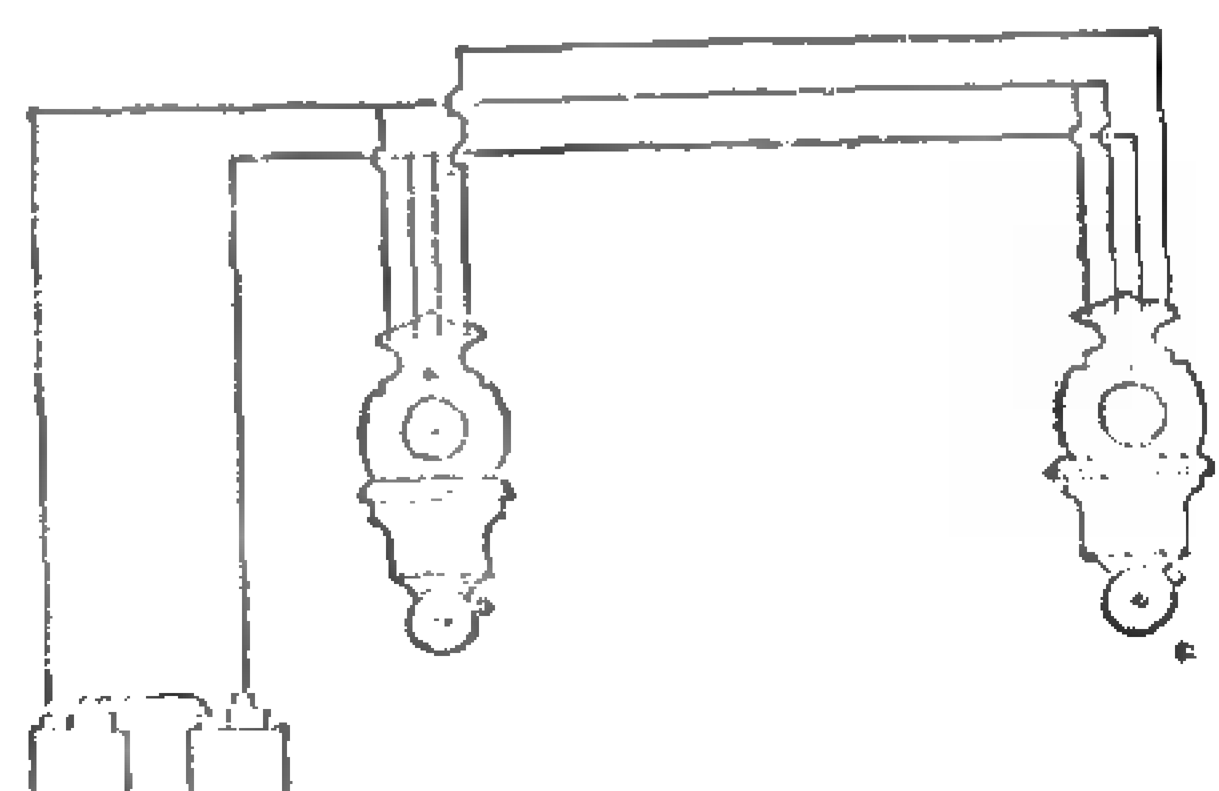

FIG. 12.

type of telephone.) In Figs. 12 and 13 are represented the arrangement of two telephones, with their respective bells, using either two or three line wires

only. The arrangements shown at Fig. 14 is intended for two or more sets, all in communication with another marked No. 1. This latter, by means of a

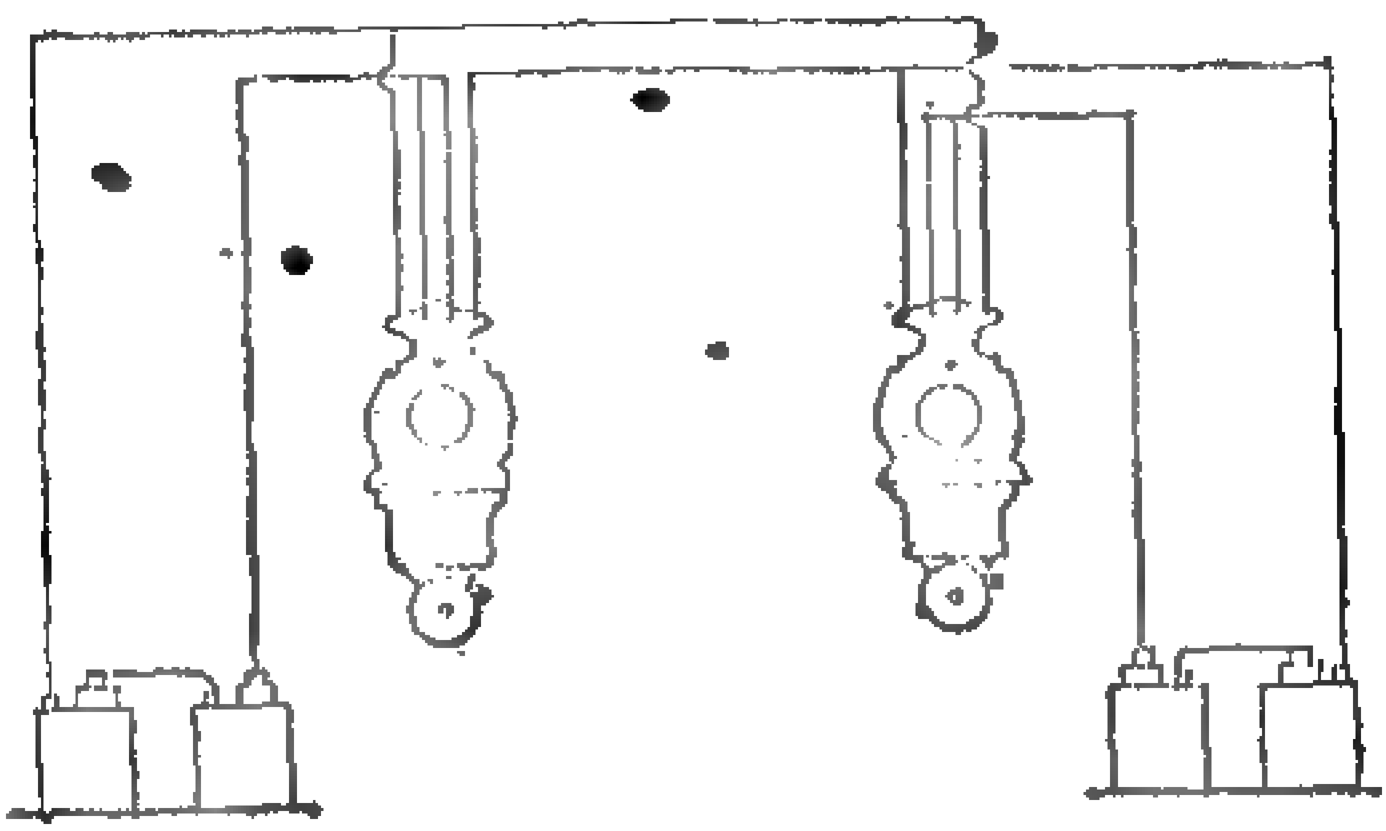

FIG. 13.

set of pushes, T, can communicate with all the others, 1, 2, etc.; but these latter, having but a single hook, can only speak through to No. 1. The plan shown at Fig. 15 represents the mode of connecting up the

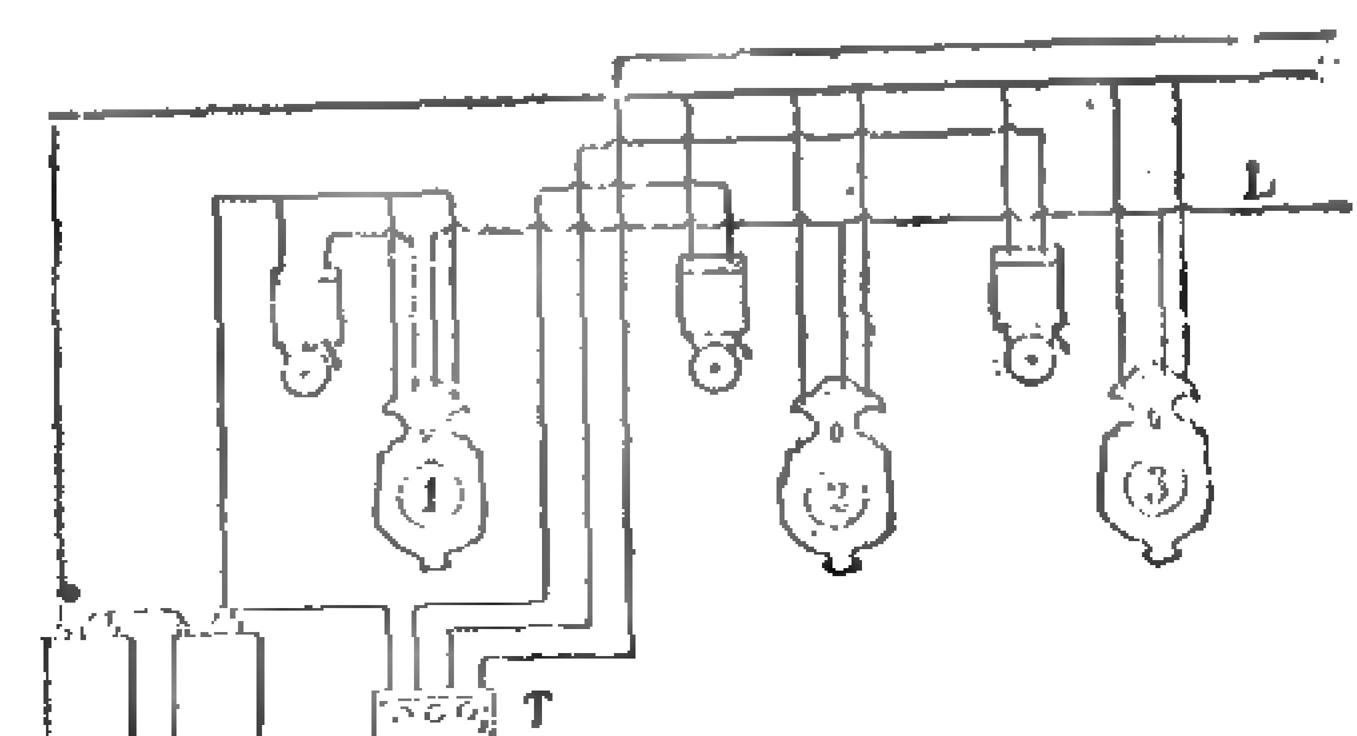

FIG. 14.

telephone C that can be called up by several others, such as 1, 2, 3. In this case it is advantageous to insert an indicator frame (similar to those used for

bells), so as to warn the listener at the telephone, C, from whence the call comes. Such an arrangement is useful, for instance, in an office where the door-keeper may be called by his employer.

On the other hand, it is very often necessary that the telephones should be able to correspond with one another, indifferently, in which case the connections are carried out according to the plan represented at Fig. 16. In such an installation the bells, with their

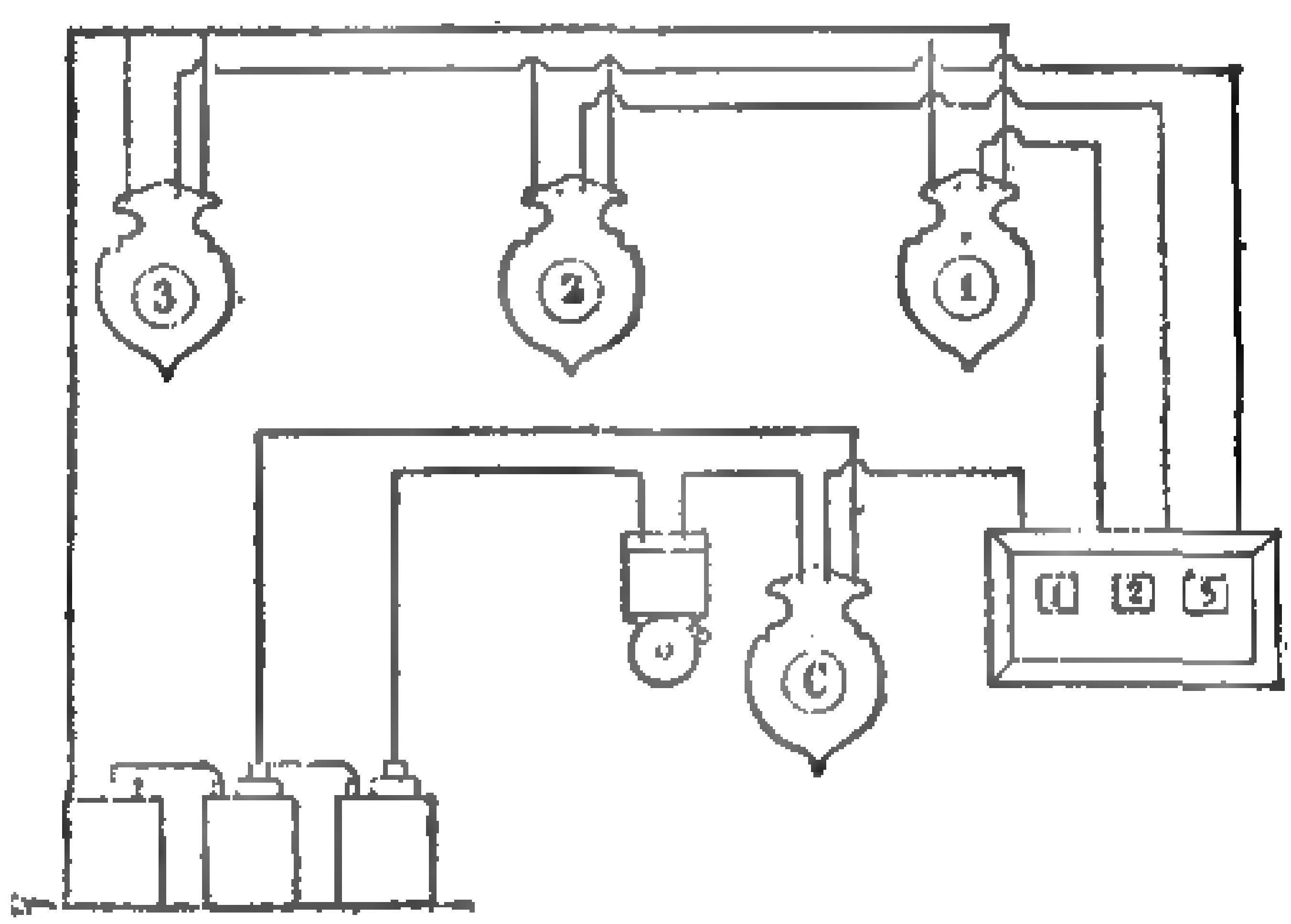

FIG. 15.

respective pushes, are separated from the telephonic apparatus, the hook whereof acting as the switch only to interrupt the current to the microphone. More than three telephones can be used, provided, however, that the last of the series be connected in a manner similar to that marked No. 3. Besides, the internal circuit of the telephone may require a slight modification to suit the purpose. When the distance between the two microphonic stations becomes considerable, one of the line wires may be done away with and

replaced by an earth return. In order to work the bells, it would be necessary in this case to use relays R R (Fig. 17), which are generally fitted in the bell cases. These serve to close the circuit on the local battery: *s s* are dischargers or lightning guards for the protection of the line L.

When several telephones are intended to communicate with one another indiscriminately, or when two

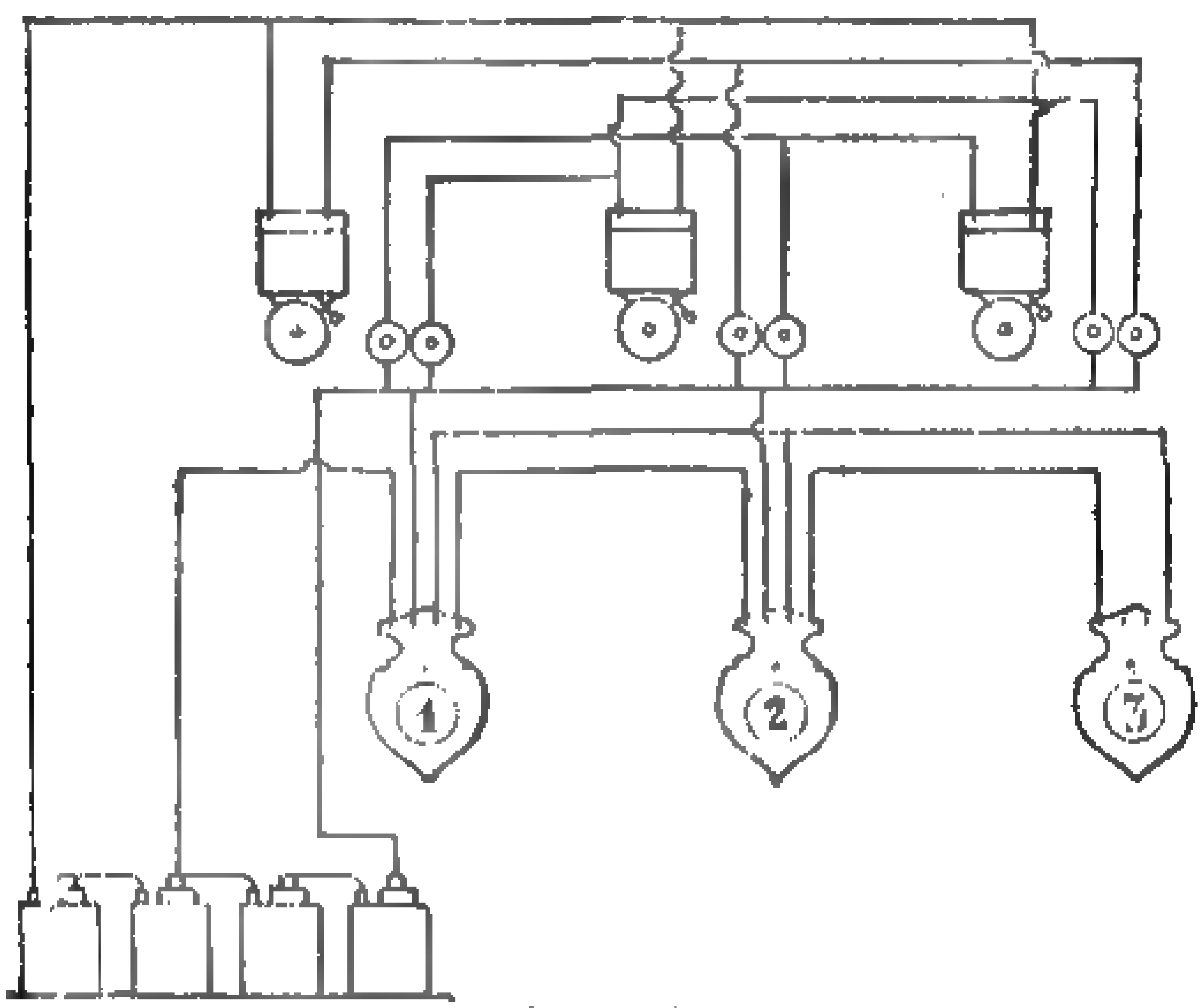

FIG. 16.

telephones only are required to communicate with a third, both the simplification and the artistic appearance of the arrangement demand the use of a central telephonic frame, consisting of the telephone and a switch, with an indicator and its respective bell. The switches on this frame are of the plug type, one extremity of which is connected to a cord, whose internal conductor joins it up to the binding-screw corresponding to the line wire of its own telephone.

Telephonic frames are generally constructed of the "falling door" type, which close the bell circuit continuously. These are, however, rather expensive; and for circuits not exceeding a few thousand yards in distance it is possible to employ, with advantage, bobbins wound with turns suitable to the distance which they are intended to work. Usually, telephonic frames are constructed so as to be fixed to the wall. However, there are other types that meet different

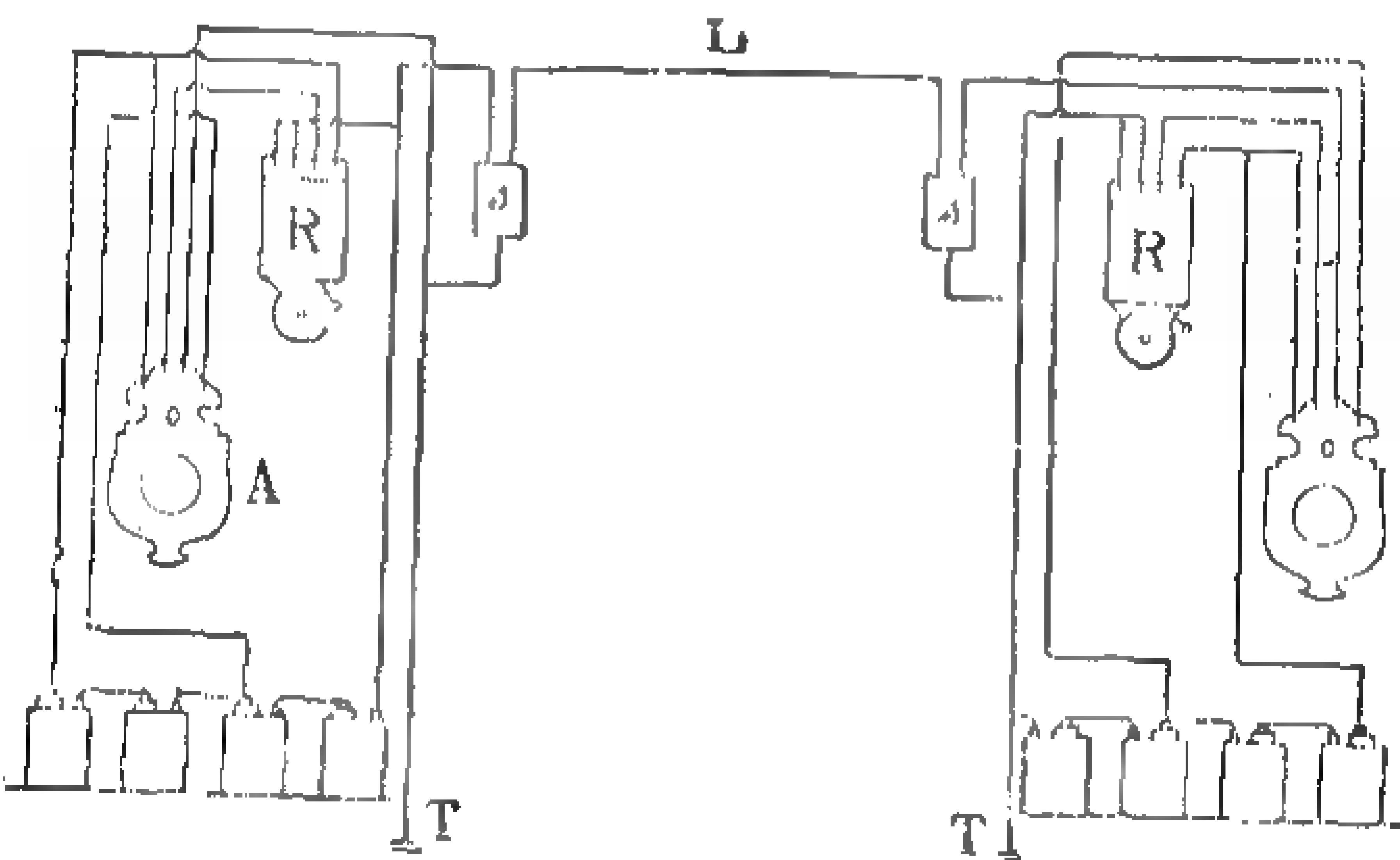

FIG. 17.

requirements; some of them being very small and elegantly mounted for use on the table in better-class establishments. Our illustration, Fig. 18, represents one of these, wherein are clearly shown the telephone reduced to the smallest possible dimensions compatible with perfect action, the indicator, the plug switch, and a keyboard for other casual calls. In this the bell is not included, as it is generally found convenient to have it distinct, so that it should not

Fig. 18

needlessly disturb the listener who has to remain near the apparatus.

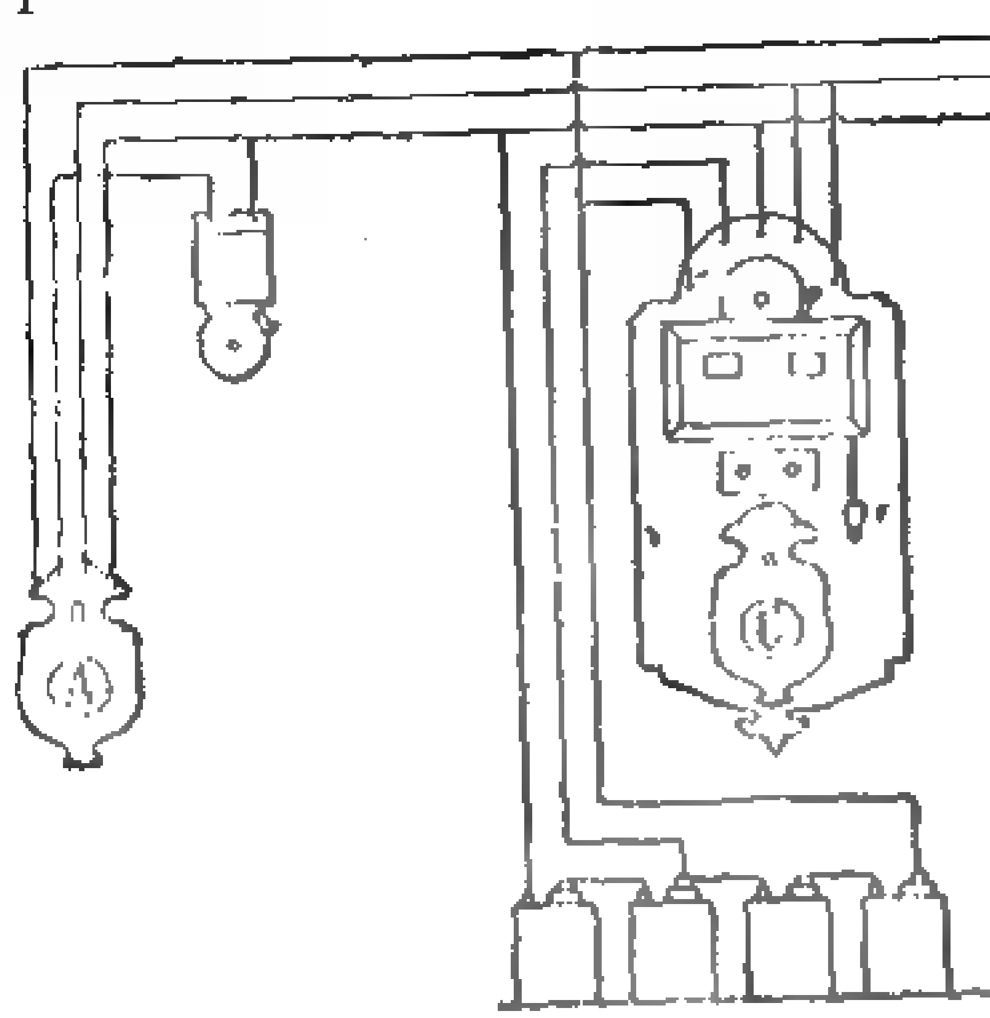

FIG. 19.

Our plan, Fig. 19, shows an installation of a central telephone, C, that can be called, or can call upon, two lateral stations, A, B. However, these latter cannot

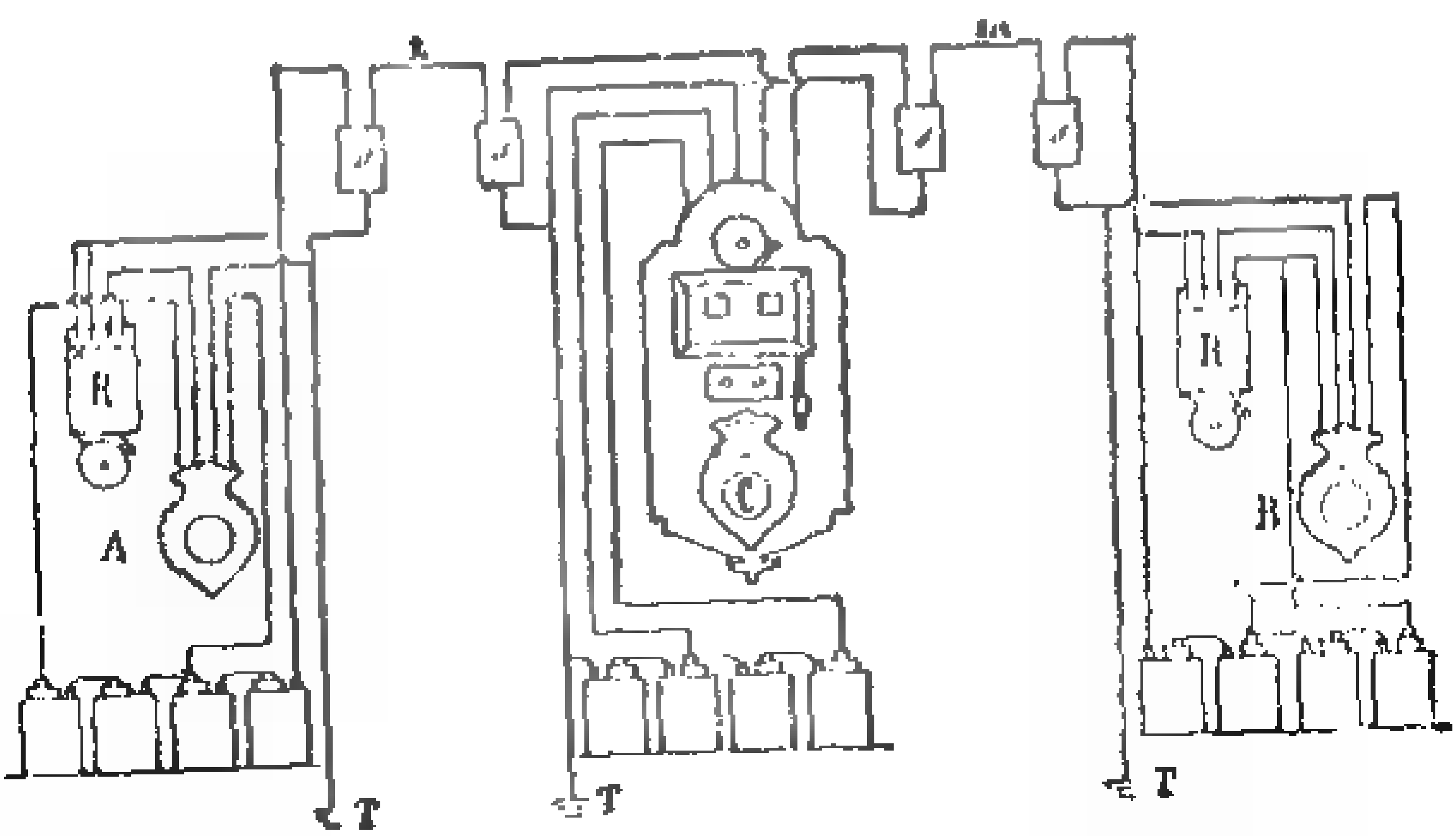

FIG. 20.

speak to one another; it being necessary, if this be desired, to arrange matters as shown at Fig. 21. The

communication plug, *s*, must normally be removed from the hole. It is only when the central station is called by station A or station B, or that it wishes to call upon them (in the first case, his indicator will show this), that the plug is to be put in either the left-hand or right-hand hole; bearing in mind that the plug must be removed as soon as the conversation is finished. When this arrangement is carried out for a distance of several miles (compatible with the carrying power of the instrument employed), it is

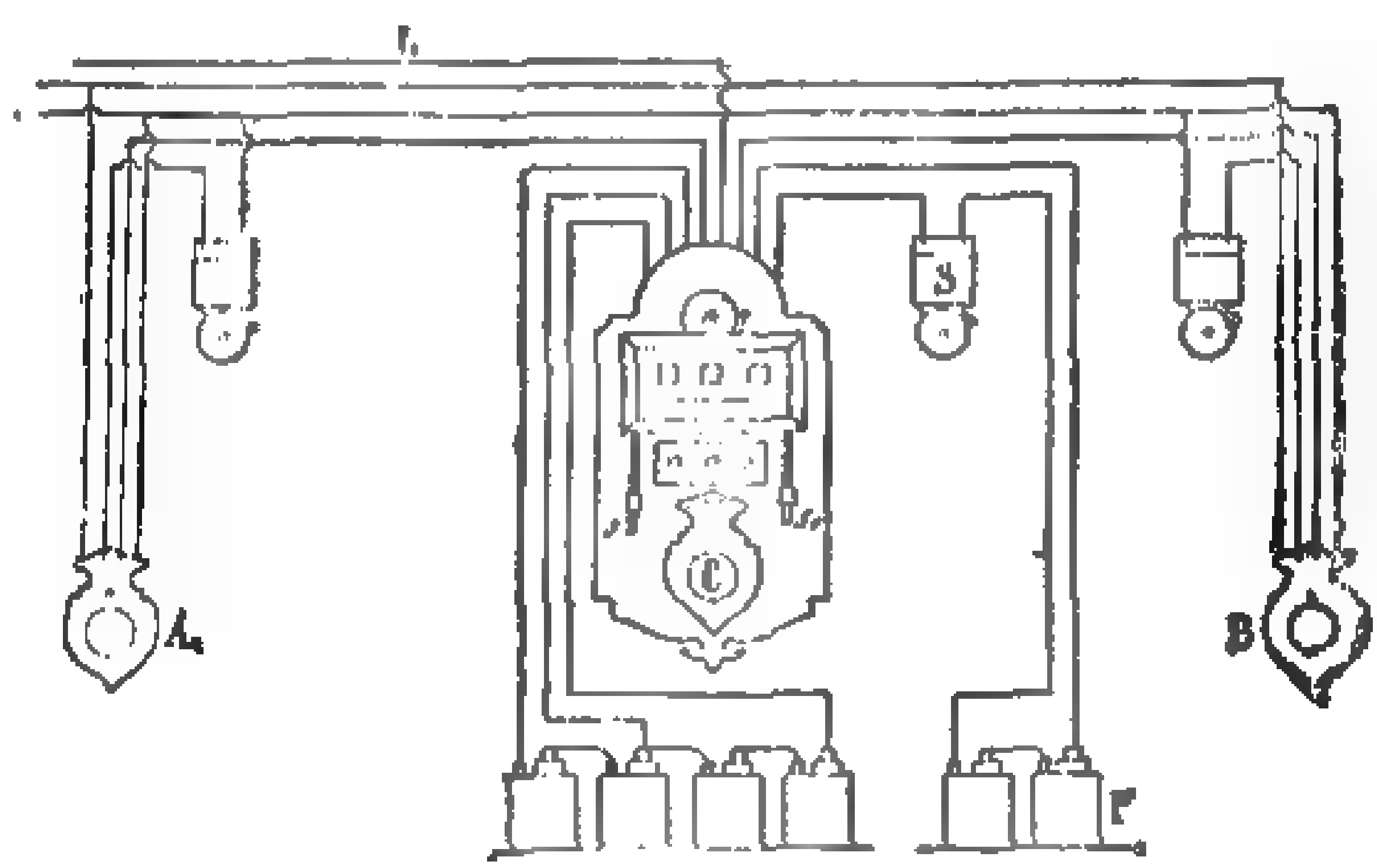

FIG. 21.

necessary to insert a battery at each telephone and to fit the bell with relays, R, R; to safeguard the whole by lightning conductors, *s*, *s*, which are placed along the external lines, L L; and lastly, to make use of the earth as a return (see Fig. 20). Moreover, if the telephones, A, B, besides having to speak to, or with, the central one, it would be necessary to fit the switch with two plugs, *s s* (Fig. 21), and with a bell, S, actuated by a battery, P, in order to notify to the central station to break the communication when the

two laterals have finished conversing. The sketch represents the arrangement of three telephones (one of which is not shown), with the line, L, to the central one. When special conditions render it imperative, the same installation can be carried out with a set of batteries for each telephone, and in such a case, for the special circuit. As the bells cannot be fitted with relays, it is recommended that the earth resistance, T T, Fig. 22, be negligeable; or, at least, very small

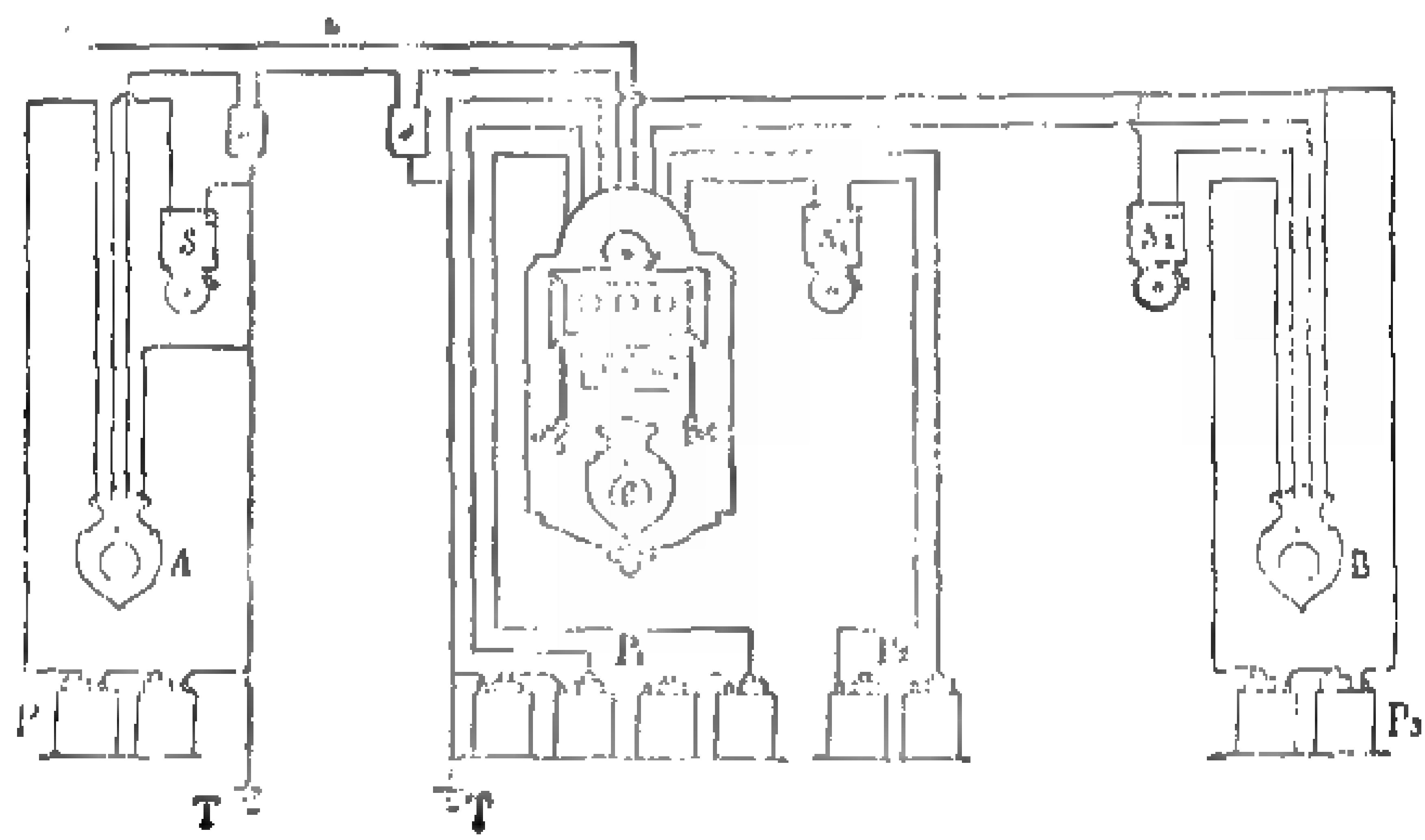

FIG. 22.

indeed, taking every precaution that it be carried out with the greatest care.

We now pass to give illustrations of the two modes of connecting telephones of the Berliner and Richard type, with two cells (Figs. 23–26). In the general way, we may observe that the employment of two batteries is necessary when the distance between two stations exceeds certain limits—that is to say, when the sparing in line wire makes up for the second

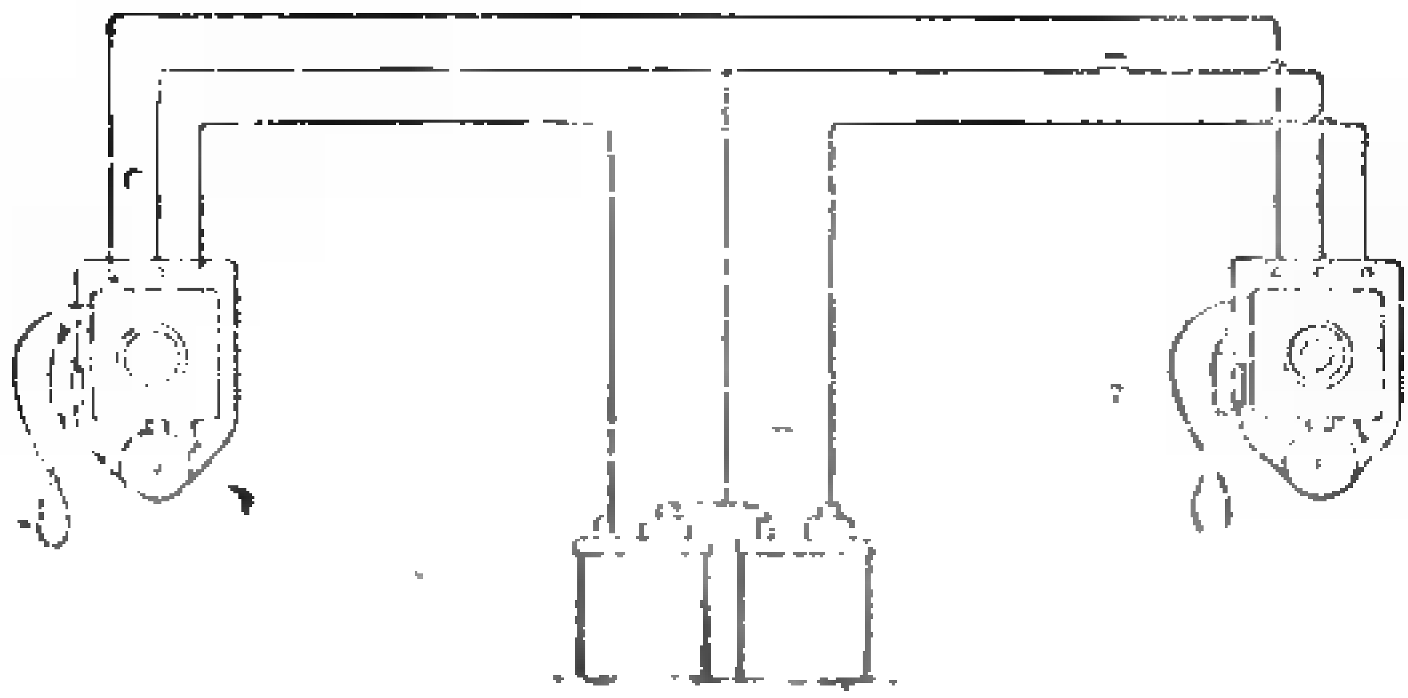

FIG. 23.

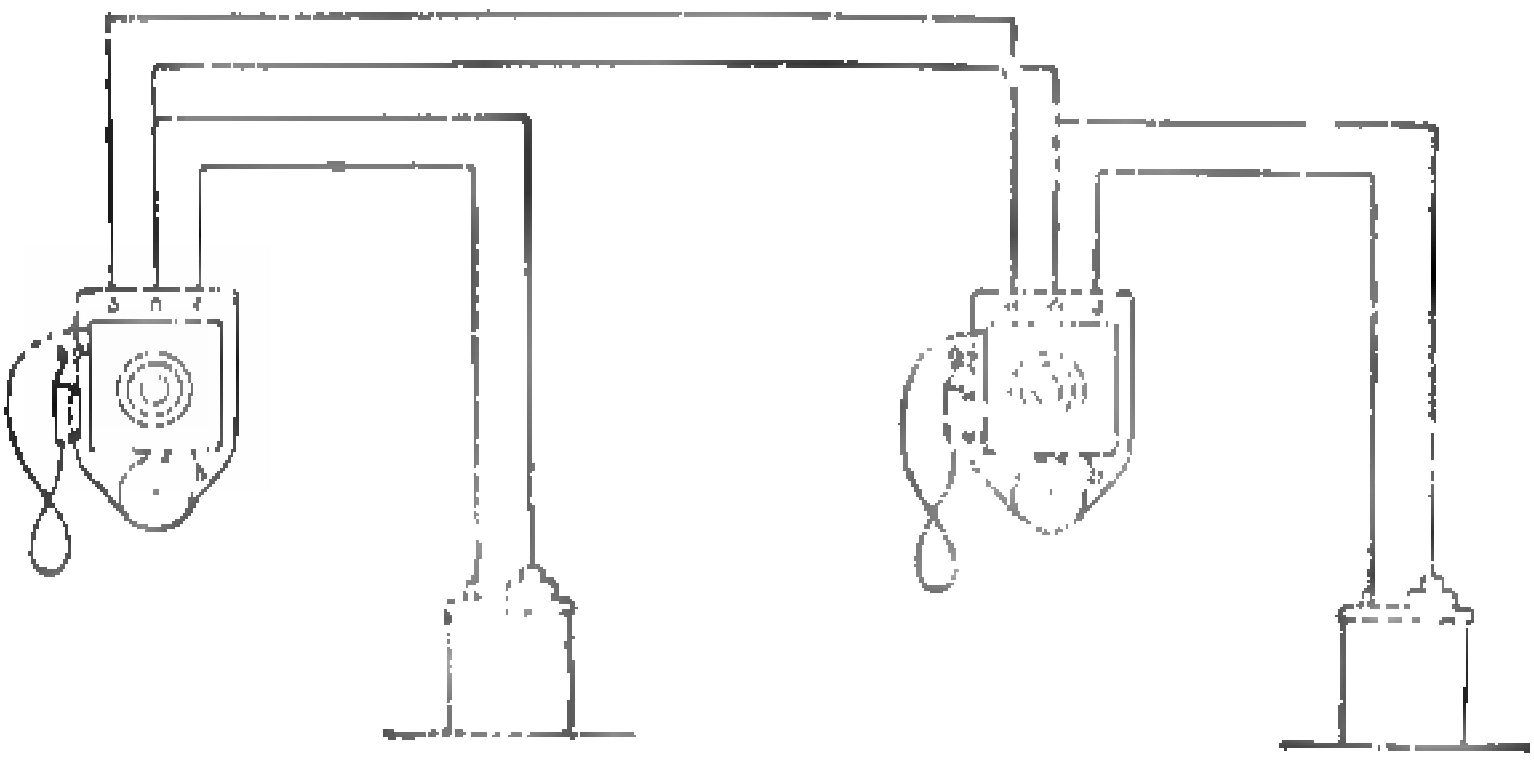

FIG. 24.

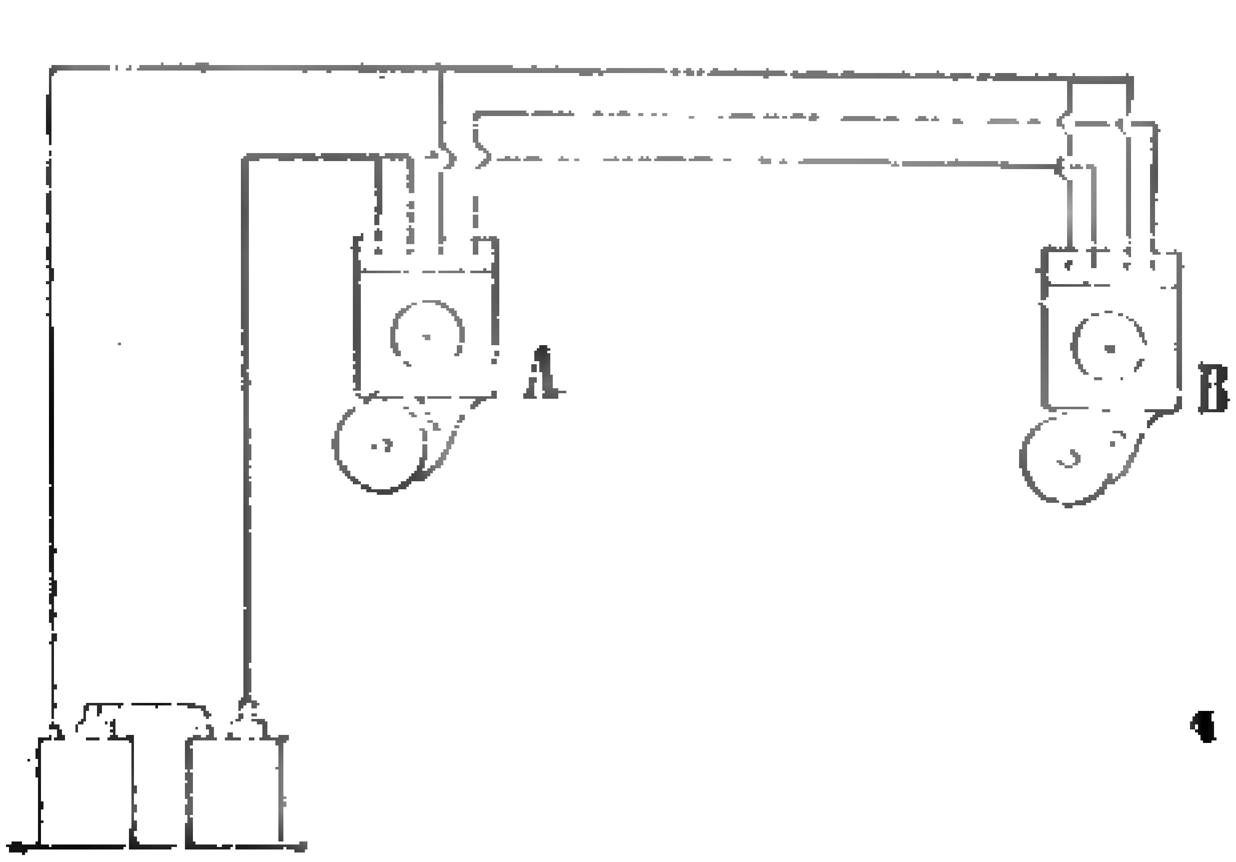

FIG. 25.

set of batteries. Under the fanciful names of "hand combinations," "citophones," etc., many very convenient forms of combined transmitters and receivers have, within the last few years, been placed upon the market, and these are furnished with a spring switch within the handle that serves at once to support the transmitting microphone and the receiving telephone, and to retain them at a convenient distance from both mouth and ear. These are fitted with cords as usual, furnished with rings or tabs at their extremities, to enable them to be connected up at will to the bell, battery, or other pieces of apparatus, with which they are to work. These cords may, as in the case of ordinary telephones, contain more than a single pair of conductors, so that the user may, if desired, place himself in communication with one or more existing stations. At Figs. 27 and 28 we give two modes of connecting up such instruments. Our first sketch illustrates the manner of applying such "hand" telephones to an existing bell circuit. The usual pushes must, however, be replaced by special pushes having a plug contact for communication, and hook for suspending the telephone when at rest. The apparatus in A is a special construction, and should be a fixture; while telephone B is portable, and may be connected up at will from one to another push by means of the pin plug. Those portions of the sketch that are marked in dotted lines—that is to say, from the bell to the indicator frame—indicate the connection that must be cut out when the telephone is fitted to the bell circuit.

In our second sketch (Fig. 28) we show the connections required for mutual conversation between

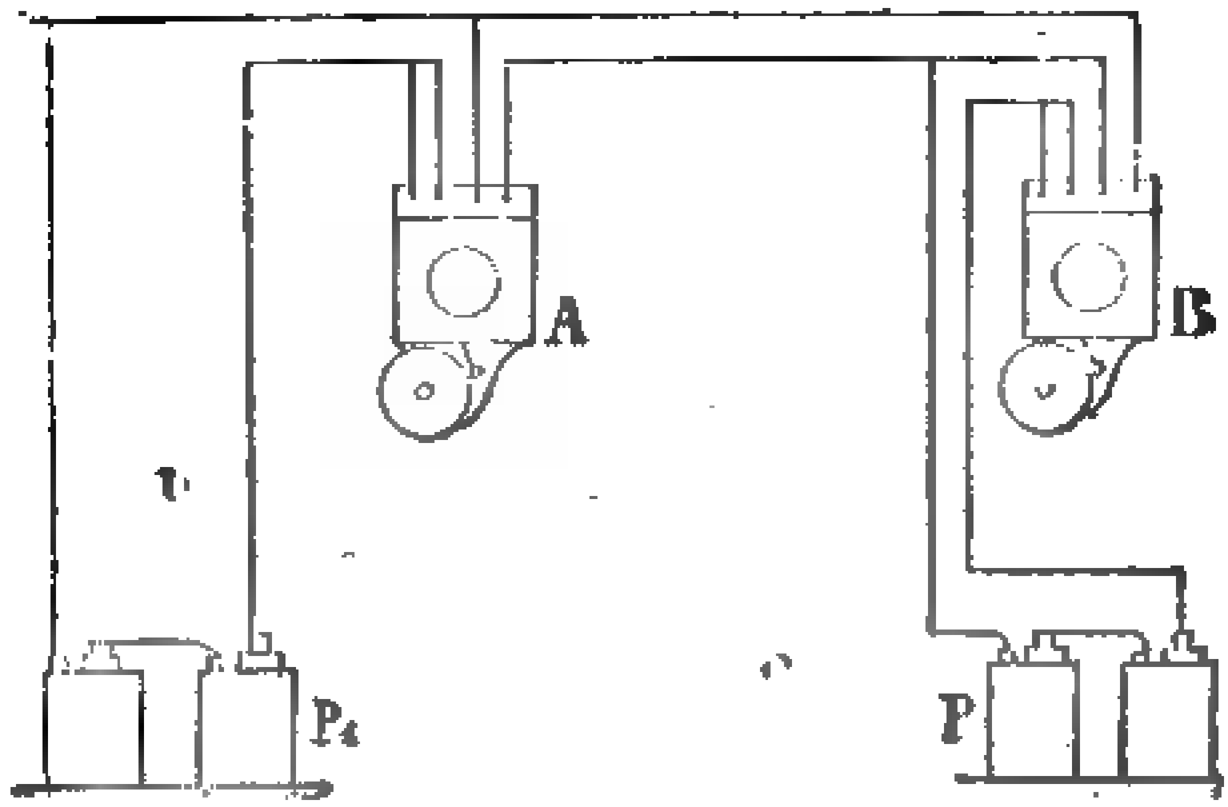

FIG. 26.

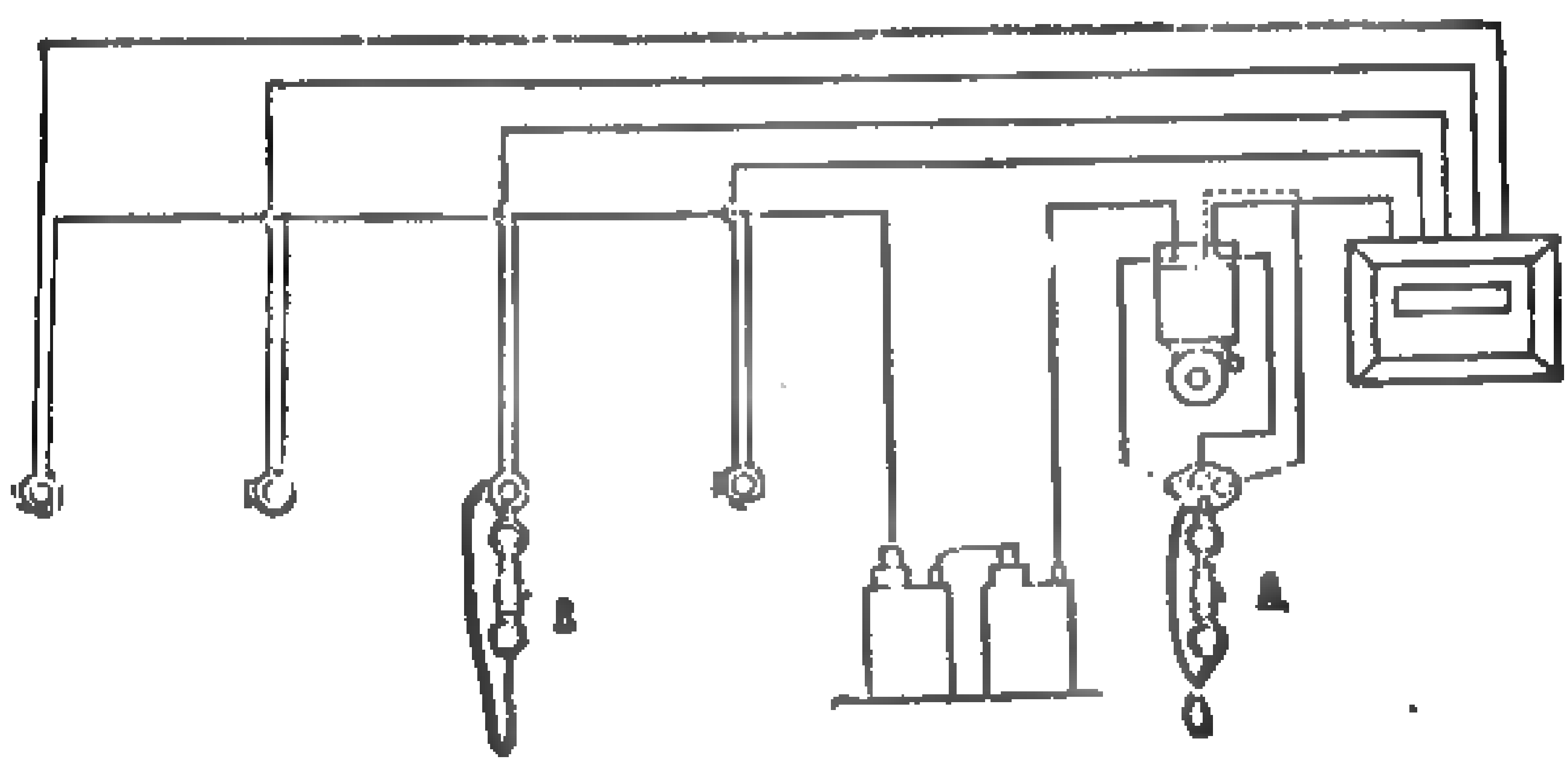

FIG. 27.

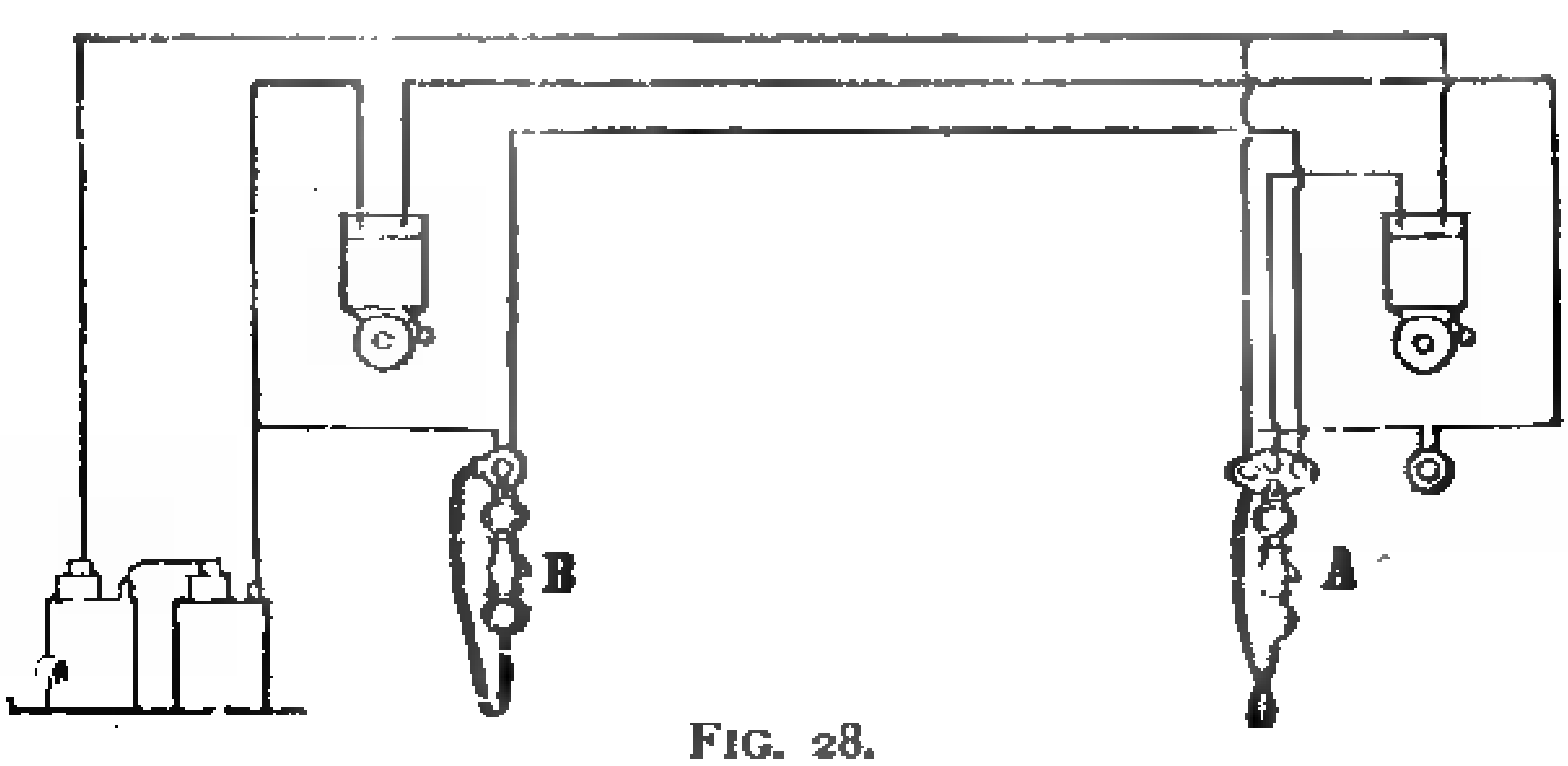

FIG. 28.

two rooms, by means of a pair of these instruments. Telephone B, in order to call, makes use of the special push annexed; while telephone A requires the application of a common push. To secure the interruption of the current in the circuit while speaking, these instruments are provided, as already mentioned, with a spring switch in the handle, which must therefore be kept firmly compressed while conversation is being carried on.

CHAPTER II.

Long-Distance Telephones.

IN our last chapter we have dilated somewhat on the use of telephones for the use of what may be called "domestic purposes," and, as in practice one cannot conceive an electric telephone working—however short the distance—without a microphone, we have also pointed out the essential principle on which its working depends. We now propose to study the details of true telephonic working (*tele*, far, and *phone*, sound), by which we understand the great and extended use made of a means of communication by which the spoken word is taken from city to city, and places us in instant communication with far-off countries. Telephony has for its scope the transmission of speech to a distance. Its foundations are based in part on certain principles of acoustics, which we should do well to bear in mind.

It is necessary, first of all, to note that sound is propagated in bodies by waves of longitudinal vibration, and that in a sound three principal qualities are to be distinguished: (*a*) The *pitch*, which depends upon the number of vibrations per second. For a given note, whatever be the instrument that emits it, the duration of a complete vibration is always the same, as, for example, $\frac{1}{435}$ of a second giving A of the musical scale; or, what amounts to the same thing, the note A, of the second space in the treble

clef, requiring vibrations at the rate of 435 per second for its production. (*b*) The *volume*, which is a function of the amplitude of the vibrations set up, and by means of which a loud sound can be distinguished from a weak one—the greater its volume, the farther can it be heard. (*c*) The *quality* (*timbre* or *Klangfarbe*), which enables us to distinguish two sounds of the same pitch emitted by different instruments. This difference in quality is due to harmonics inherent to the resonance of the different parts of the instrument. The harmonics have less amplitude than those of the fundamental note on which they overlap. The simultaneous transmission of a sound accompanied by its harmonics may be compared to the propagation of a huge wave, the surface of which is covered with a number of ripples that are carried along with it. The fact that harmonics enter largely in the production of speech is due to the action of the air projected by the lungs on certain membranes of variable tension, called Vocal Cords, that are situate at the bottom of the larynx: these vocal cords give rise to the fundamental sound, that may be the same whatever be the letter of the alphabet pronounced; and the configuration of the mouth, at the instant of the emission of this sound, determines the production of the harmonics characteristic of each letter. In fact, in order to speak, the tongue, the larynx, the lower jaw, and the lips, all have to fulfil certain movements. These have been carefully studied and accurately analysed, and their mechanism is well known. By virtue of any given one or other contraction of the mouth, such or other sound will result. The articulation of the vowels, or of the

consonants composing the words in different languages, complicates the operation. A sound, a cry, a word, strikes the air, and this impact throws it into vibration: the air carries that sound, and transmits it to a greater or a lesser distance. The original force of the impact—or starting intensity—the atmosphere being more or less charged with moisture, the contrasting influences of many noises travelling at the same time in opposite directions through the indispensable medium, will modify, though without a serious weakening of the sound, the distance usefully traversed.

Has attention never been directed to the fact that in a quiet, tranquil atmosphere, in the country, or at night, one's voice will travel to great distances? This seems to us quite natural, because we meet with this phenomenon at every moment. The mouth has spoken—and all around it within a radius (the dimensions depend upon an infinitude of circumstances) everything—trees, stones, air; especially air, which is one of the vehicles favoured by sound; speaks, or at least repeats the speech. The initial motion imparted propagates itself until its last wavelets become inappreciable to us. The vibrations set up by the lungs penetrate a wall, a closed window, or a hedge, and such a transmission awakens no surprise. In their travels they encounter the ears of animals and of men, reach their brain, and their intelligence, through the conductors of their system. The dog recognises the voice of its master, barks, and runs to him. Man, at a great distance, on being spoken to, understands and answers, and conversation is set up.

But what is this vibration that conveys speech?

Air is the necessary vehicle of sounds. Under the bell of the air-pump the ring of a bell becomes ever less discernible in proportion as the air is removed therefrom; the clapper is still seen to move, but the ear has no cognisance of the sound. Air, laden with moisture or fog, conducts the sound of the voice but little; while, on the contrary, a solid body conducts it perfectly. Who does not remember having amused himself as a child by applying to his ear one end of a long beam of wood, at the other end of which a playmate scratched with the point of a pin, or whispered gently? A table can be made to speak, and all its molecules will enter into vibration. A valley, a road lying between flanking rocks, a large corridor, transmit sound perfectly. And what about Echo—that nymph, hidden among the rocks, that sends back the spoken word? In many cloisters, and in numerous churches and cathedrals, exceptional disposition of the vaults are to be met with that repeat speech excellently. From practical observation of these facts, united to a diligent study of the phenomena, the speaking-trumpet owes its origin. The air is localized, as it were imprisoned in a funnel, and the sonorous waves being consequently condensed, are not able to diffuse themselves in transit, to the right or left. Consequently, the voice reaches its destination clearly and with fulness, without being dissipated on the road.

Solid bodies conduct sound well, and on this fact is based the string telephone, which consisted practically in two small tambourines, the stretched membranes of which are connected together at the central portion by means of string extending the whole

distance that the sound was intended to traverse, the uniting cord being kept tense. Although by this means it is possible to transmit speech distinctly to a distance of a hundred and fifty yards and more, the string telephone has entirely disappeared since the electric modification came into being.

The first experiments in this direction by Reys, Wray, Gray, Varley, and others, led only to the production of instruments capable of reproducing musical sounds, but not speech. A certain M. Bourseuil, a director of the post office of a little provincial city in France, in 1854, appears to have begun a series of experiments in electric telephony, and has left a record of some of these in a paper called "L'Illustration," by which it would appear that the transmission of human speech along an electrified wire could be effected. A want of means and publicity put a stop to this inventor's trials, so that he is now almost forgotten. It was reserved to Graham Bell, in 1876, to resolve the problem of the reproduction of articulated speech at a distance by means of his telephone, now spread by the million over the entire world. So astounding were the effects obtained with this simple instrument, that Lord Kelvin (then Sir William Thomson) did not hesitate to declare that it was the marvel of marvels.

The electro-magnetic telephone devised by Bell (and of which we have given a description in the previous chapter) is no longer employed at the present day as a transmitter; its present use is as a receiver only, owing to the fact that the induced currents set up in it are very weak. When it is desired to speak to any considerable distance, it is necessary to discard

the principle of transforming the mechanical energy of the sonorous waves directly into electrical energy, and to utilize the air vibrations to modify the intensity of the current set up by a local battery, somewhat in the same manner that a tap permits of the variation of volume in a jet of water or steam. The transmitter plays precisely the function of such a tap. Messrs. Edison and Hughes, 1877–1878, undertook special experiments for this purpose—the former by placing in circuit with a battery and the line, coarsely-powdered carbon, the resistance of which is variable with the pressure to which it is subjected: this difference being due to the movement imparted by the sonorous waves to a diaphragm resting upon the carbon granules; the latter by taking advantage of the variation in resistance presented by movable conductors under the influence of sonorous vibrations in the air. These researches culminated in the perfecting of the microphone, which, united to the Bell telephone, has increased the importance of this latter one hundredfold. It is to Hughes that we owe, in great part, the universal employment of telephones—a specific revolution which marks an epoch in the history of the scientific discoveries of the nineteenth century.

We would here call attention to the necessity of using an induction coil in telephones destined for long-distance service. A simple microphone and battery enables us to transmit messages to a much greater distance than a Bell telephone. It is more than sufficient for indoor communications; but a limit is soon reached, beyond which intelligible speech is no longer transmissible, as the sounds come out imperceptibly. The reason is not far to seek: in

proportion as the line is lengthened, its resistance increases, while the variations in resistance produced by the volume of the sonorous waves on the microphonic contacts remain constant. Consequently, the influence of these variations on the total resistance of the circuit diminishes, and the undulations in the current become proportionately weaker. It must be noted that the variations in the current are inversely proportional to the square of the total resistance in the circuit. It, therefore, diminishes most rapidly

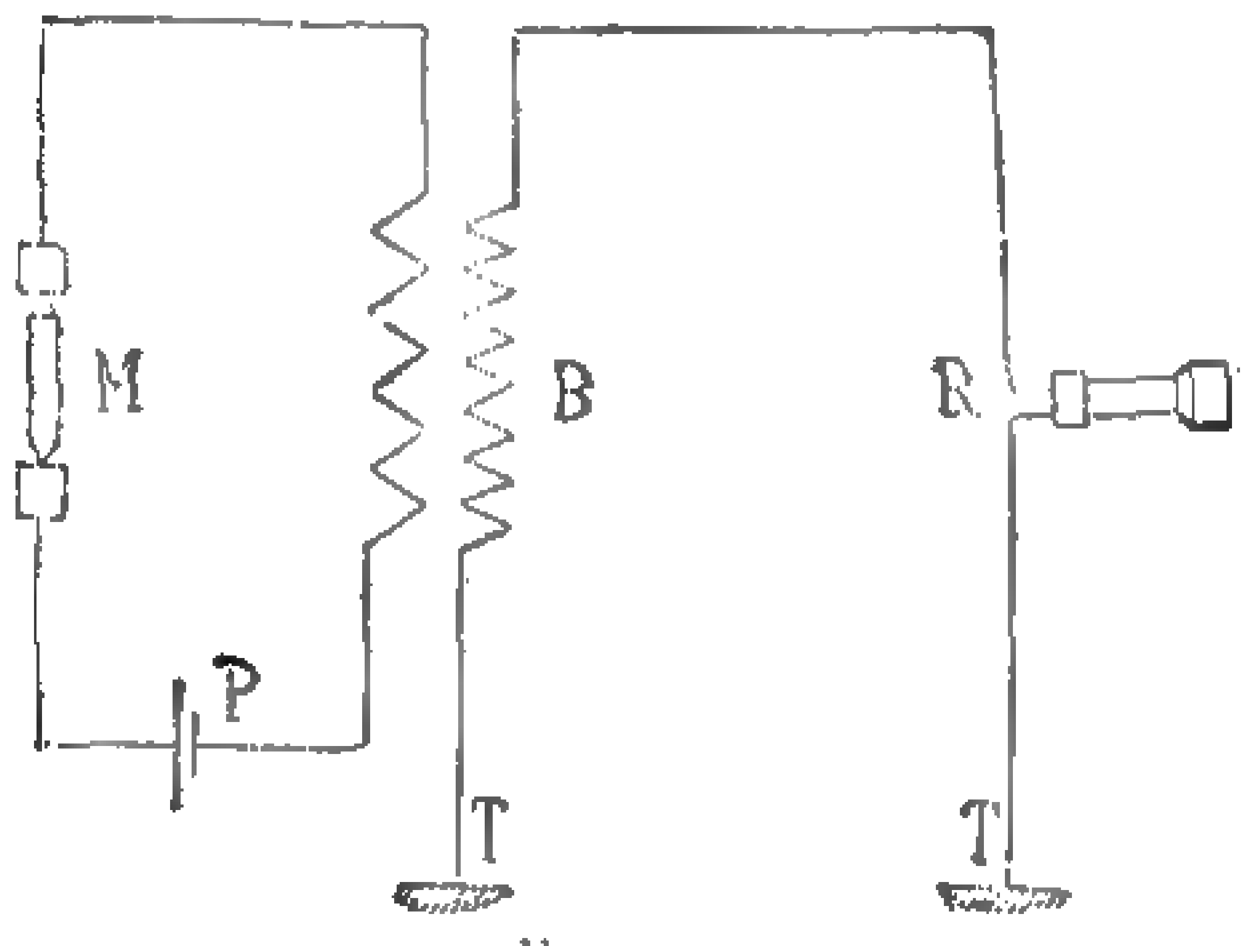

FIG. 29.

when the length of the line is increased; on the other hand, the permanent current that traverses the receiver attracts its diaphragm, and diminishes its sensibility. The question arises, Is it possible under these conditions to telephone to a great distance? Edison, with his usual acuteness, intuitively resolved this problem by the use of induction coils. Fig. 29 is a diagrammatic representation of the purpose served by the induction coil, and it is so clearly shown that it does not call for a lengthy description.

The primary convolutions of the coil consist of a few turns of thick wire, as shown by the heavier lines in our sketch, and this is put in circuit with a microphone, M, and the battery, P, while the ends of the secondary winding, B (which is of much finer wire), are connected, one to earth, T, and the other to the line-wire leading to the receiver, R, and thence back to another earth, T. By this ingenious device, whatever be the length of the line, the microphone contacts are connected by a circuit of trifling resistance, and the variation of pressure in these contacts give rise to electrical waves of great magnitude in the primary circuit. In the secondary circuit electromotive forces are set up, which are of greater intensity in proportion to the greater number of turns with which the secondary is wound. It is therefore possible by this means to set up currents of sufficient tension to travel along a line of very high resistance.

It is not possible to use induction coils on an open magnetic circuit, because the coercive force of a closed circuit would militate against the rapid variation in the magnetic flux. For apparatus destined for the transmission of messages to a great distance, the core of the coil is made up of a bundle of straight iron wires of about No. 25 gauge, rather over a quarter of an inch in diameter and about three inches long. The primary, or coarse wire coil, consists in two layers of insulated copper wire, No. 18 gauge, having a resistance of about $\frac{1}{8}$ of an ohm. The secondary is wound with several hundred turns of No. 36 silk-covered wire, until its resistance reaches from 125 to 250 ohms, according to the distance to be traversed.

CHAPTER III.

Telephonic Lines and Stations.

ELECTRO-MAGNETIC GENERATORS AND BELLS.

SOME means of signalling, by which attention can be called, is absolutely necessary between any two telephonic stations that desire to communicate with one another. In some electro-magnetic telephones of large dimensions attempts have been made to effect this by means of the same apparatus that serves for transmission, as, for example, in the acoustic cornet of the Siemens' telephone. But bells are always preferable, and these may be actuated either by battery power, or, better still, in point of view of simplicity, by a little magneto generator of the Siemens' type, to which, by means of a small handle, a rotary movement can be communicated in a fixed magnetic field. If a battery be used an ordinary bell must be employed. If, on the other hand, the magneto generator be preferred, a special polarized bell acting as described below must be made use of, in which two cores of an electro-magnet and an armature are polarized by a curved permanent magnet. The alternating currents derived from the magneto generator, and which traverse the coils of the electro-magnet, alternately weaken and strengthen the magnetism of the cores, thus attracting the armature (which is movable upon

an axis passing through its centre), causing it to approach successively the two cores, carrying with it a clapper that, according to which of the two cores is attracting it, will strike now the one, and now the other of the two gongs which constitute the real "call" apparatus (Fig. 30). The separation of the cores of the bobbins from one another reduces their self-induction to such a low point that it is not

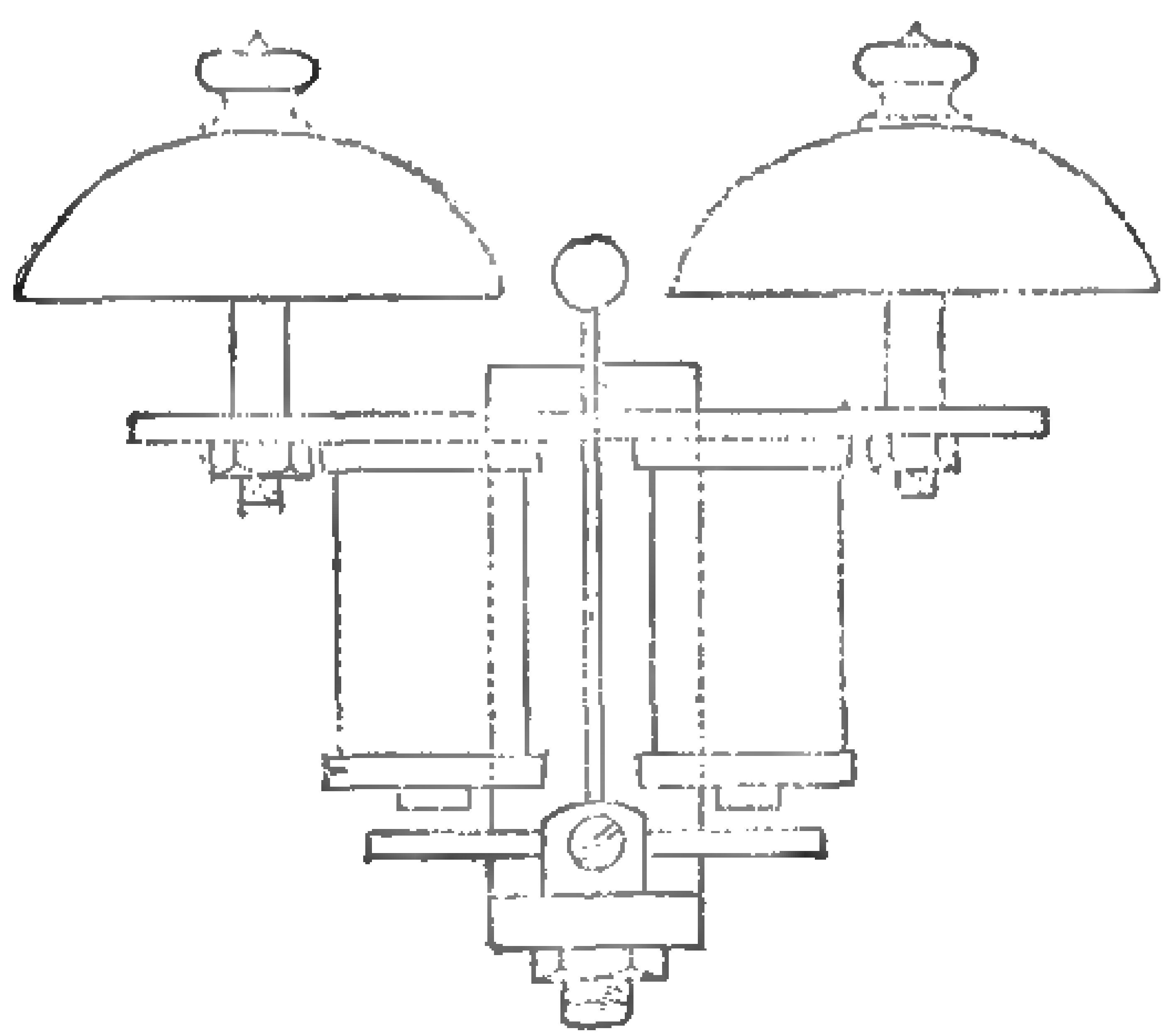

FIG. 30.

necessary to place any great resistance in the way of the alternate currents.

We now give a sketch (Fig. 31) of the internal connection. In describing this we will suppose that we have a single microphonic station in its entirety, in which the circuit is purely metallic (that is to say, the go and return lines are wires, without making use of earth at all). Where the lines (LL′) enter the station

we have a comb lightning arrester, shown at p, which has nothing to do with the circuit, except to protect it from lightning, and for this reason must be taken to earth (T). When the telephonic wires are in the vicinity of light or traction conductors, it is good practice to furnish the station with fuses lest an accidental contact should set up or permit the passage of a current, which might damage the telephones.

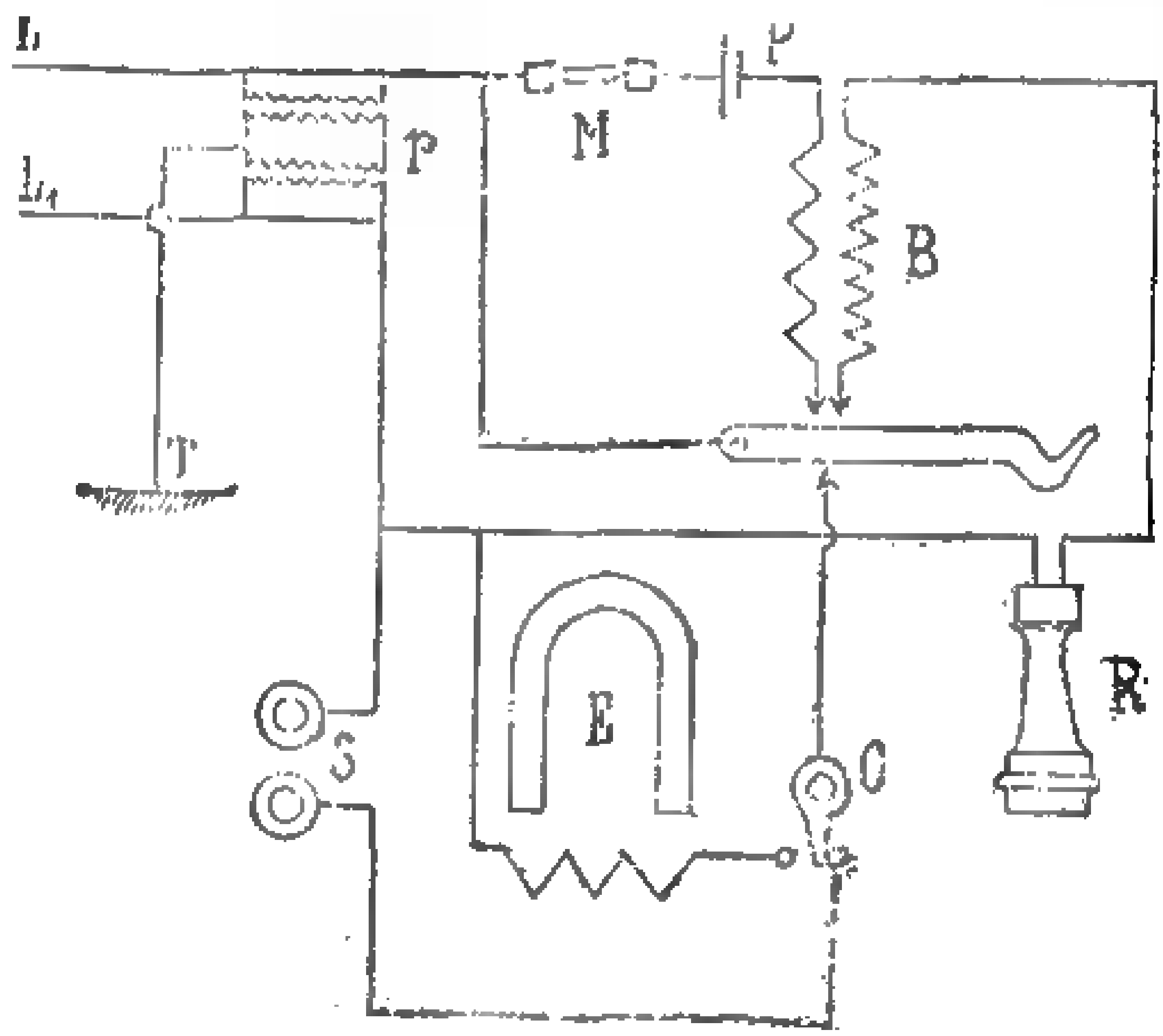

FIG. 31.

When in its normal condition the telephone receiver is hooked to a lever pivoted at one end, and sustained at the other by a counter spring. The weight of the telephone brings this bar against a lower contact, the effect of which is to put the line into communication with the bell (S), in which position it can receive the call current. Calling is effected by turning the little handle of the magneto generator (E), that automatically causes the switch (C) to act in

the necessary direction. This puts the line in circuit with the generator, and the currents are transmitted. When this operation is over the commutator returns to its original position on the other stop by the action of the counter spring. On detaching the receiver the lever closes simultaneously the primary circuit of the battery (P) and that of the induction coil (B) by resting against the two contacts shown as arrow-heads below B to the left. It is therefore possible at this stage either to transmit by means of a microphone (M) or to receive through the receiver (R). On long distance lines, or in places where there is much noise, two receivers may be used by connecting them in parallel and placing one to each ear. The general outward appearance of the telephonic apparatus to which we refer is shown in Fig. 32.

TELEPHONIC LINES.

Telephonic currents are *undulatory*, and therefore can be represented approximately by a sinusoidal function of time. The results which have been deduced for periodic currents are found to apply to them. These results go to prove that the self-induction of a circuit tends to bring about a diminution and a lag of phase of the current proportionate to the frequency of phase of this latter. Consequently higher tones are relatively weakened more than the lower ones. Besides this, they tend to retard the wave, a fact that brings about an alteration in the character of the voice, due to the mixture of the fundamental tones and their harmonics as emitted in speech. It therefore becomes necessary to diminish as far as possible the self-

induction of the circuit by doing away with any superfluous electro-magnet, and by making use of, on the line, conductors that are not magnetic.

It has been found that the limit for audible speech is reached at a distance of 315 miles when iron wire is employed, but that this distance may be extended to 2,000 miles if the line wire be of bronze. It has

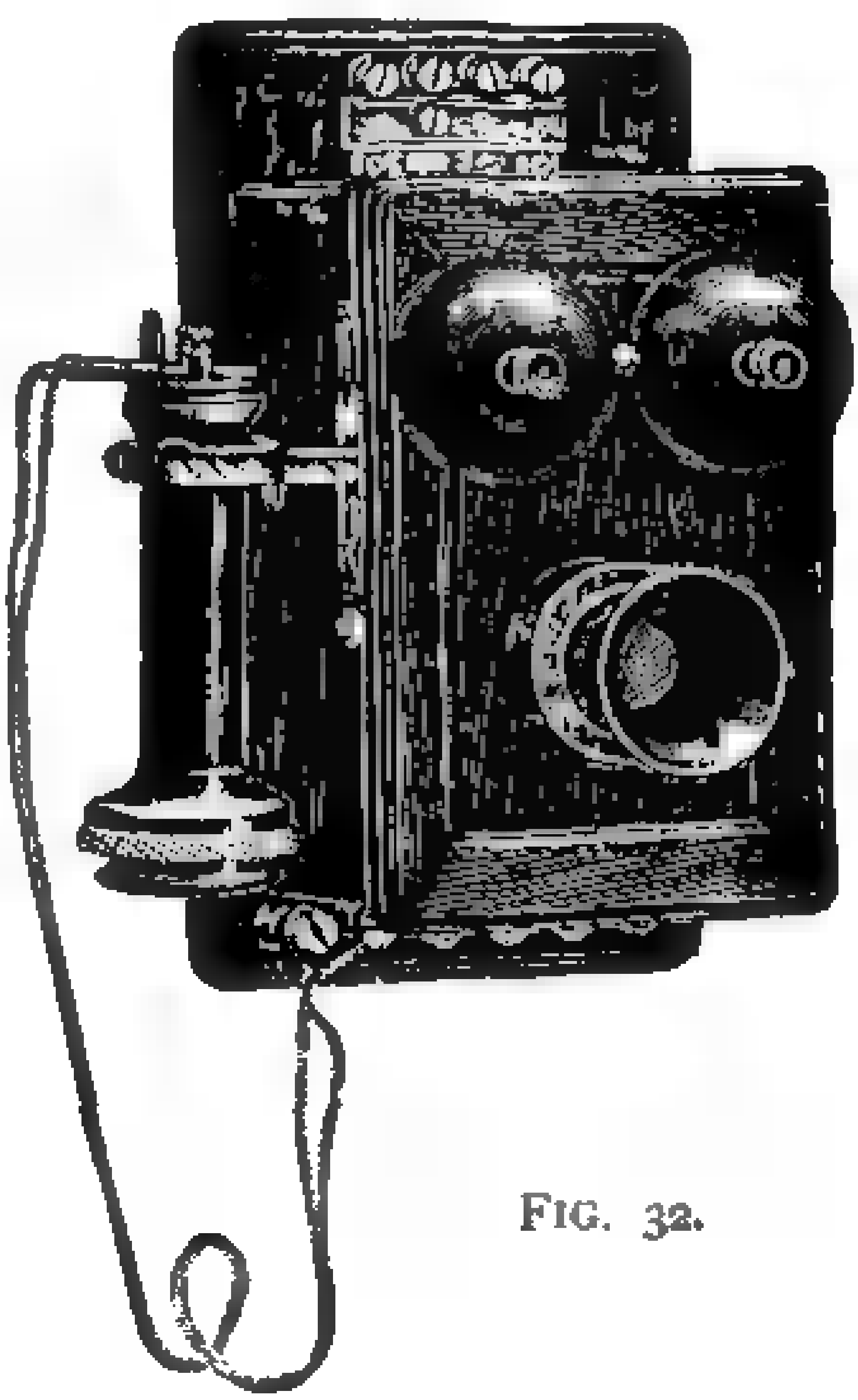

FIG. 32.

been suggested that the effects of self-induction might be overcome by means of a condenser placed in series circuit with the line. Even the capacity of the lines themselves, especially if they be under ground, acting as they then do as condensers in shunt, exerts a very injurious absorption effect, which, however, can be avoided by following out the

dictates of good practice. By capacity we understand the Leyden jar effect which a conductor carrying a current exerts on other conductors near it, and which retards very seriously the transmission of the main current.

Independently of the self-induction of the circuits, there may be other causes at work to bring about perturbations or weakness in the transmission. For instance, defective joints in the aerial lines vibrating under the influence of wind, in the earth's magnetic field, act like so many microphonic contacts on the earth currents that pass through the conductor, thereby producing in the receivers a characteristic and disagreeable hissing, which may be increased by several other causes, as, for instance, the currents produced by atmospheric discharges, or by magnetic storms, or the chemical action which continually goes on between the earth plates. The currents that are induced by telegraphic or other lines that are stretched in the neighbourhood may cause these disturbances; or, again, where an earth return is employed in the neighbourhood of a telegraphic earth, in which case a shunt current would pass along the telephonic line, and owing to the sensitiveness of the receiver, would affect it. In damp weather especially, it is not improbable that communication would be set up between the different wires of a single line, across the insulators, and the shunt currents thus obtained acquire on lines of great length or of imperfect insulation sufficient strength to act upon the telephones. This defect can be remedied by making use of double shed insulators, connecting them both to their metallic supports and to earth

by means of an iron wire. Thus, any electric current that should leak from an insulator would flow directly to earth, and would not reach the neighbouring wire.

The last, but not least, of the causes of disturbance, is that of the induction exerted by one wire upon another. When a current is sent along a conductor lying parallel to a telephone wire, two separate effects are manifested in the telephone line—namely, (*a*) a current of static discharge flows along the lines, entering at its two extremities; and (*b*) a current of mutual induction in the sense opposed to that of the main current traverses the telephone line. In consequence of the sensibility of the receivers these induced currents in the case of two parallel telephone lines permit us to hear on the one line what is being said on the other, even if this latter lie parallel to the former for a short distance only; if the distance be considerable the speech to be transmitted would be as clear as if it were on the line itself.

The first remedy proposed for this mutual induction was that of Hughes, who suggested making the ends of the different wires that terminated in a station in the form of flat bobbins so arranged that, acting by induction the one on the other, they should give rise to induced currents in the contrary direction to those which are set up on the lines themselves. Such a means is efficacious only in the case of two lines, in which, by suitably regulating the distance of the flat bobbins placed at the ends, the reciprocal induction of the two lines may be annulled. But with the increase of the number of lines, this device does not result in equal success, as it becomes more and more difficult to arrange the bobbins in such a

way that they should find themselves in suitable positions with regard to the remainder. The most satisfactory solution of this problem consists in not making use of the earth as the return for the telephonic currents, but to employ metallic circuits throughout. By this means, the shunt currents due to earth, the electro-static currents, and the hissing noises caused by terrestrial currents, are entirely avoided. The two wires constituting a

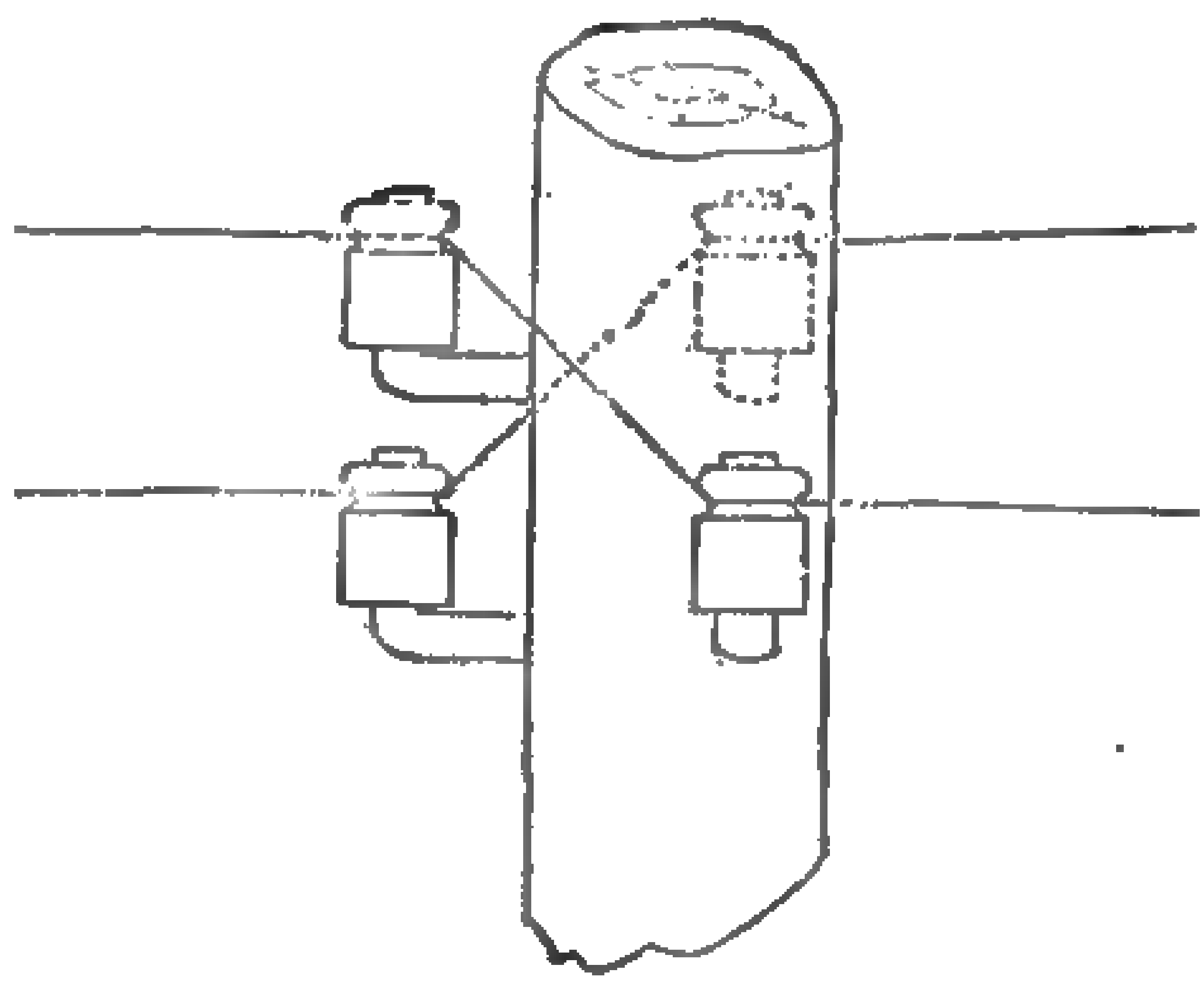

FIG. 33.

telephonic line must be placed under identical conditions as regards the surrounding line, in such a manner that the electro-motive forces of the induction set up should efface themselves in the circuit; that is to say, that the go current and the return current, being in opposite directions, shall annul one another.

In cables formed on insulated wires, the two conductors forming the circuit are twisted the one over the other. In aerial lines consisting of bare

wires the procedure is somewhat more difficult. The wires should exchange position in passing each post, in such a manner as to be influenced equally and in contrary directions by the wire in their neighbourhood. (See Fig. 33.) Notwithstanding the increased expense, a metallic circuit presents so many advantages over the earth return system that it is strongly recommended for successful telephonic installations.

AERIAL LINES.

Urban telephonic lines consist generally of bronze wires of 1·5 millimetres (No. 16, B.W.G.) in diameter. These are stretched on double shed insulators, usually supported by iron saddle brackets resting on the roofs of the houses, or by frames let into the side walls, or borne by the posts sustaining other lines. In rural lines of great length the wire used has generally a diameter of 2·5 millimetres (No. 12, B.W.G.). In these lines the telephonic wires are generally close to one another, and it is indispensable, in view of what we have pointed out in the preceding paragraphs, to adopt metallic circuits throughout, consisting of two similar conductors, arranged, as regards the neighbouring wires, in such a manner as to destroy their mutual induction. In the network of urban lines, comprising, as it does, a large number of aerial telephonic wires, the two wires of a given circuit are not usually crossed, because the mutual reaction of the induced currents brings about equilibrium in the action of the inducing currents.

UNDERGROUND LINES AND CABLES.

With a view to doing away with the inartistic appearance of a network of wires in our great cities,

preference has been given to a plan of uniting the wires to form a cable consisting of from twenty-five to one hundred strands. These cables, consisting of copper wires of about No. 20 gauge, may either be aerial, supported by a stout metallic wire, or run under ground. In cities that do not as yet possess a system of underground sewers, the cables are generally laid in conduits of cement. For these cables the insulator usually employed is paraffined cotton or jute, or some similar compound having but low specific conductive capacity. In order to render it impermeable to water, the cable is sheathed in lead. According to a method proposed by Paterson, the mutual induction and the "charge" current can be combatted in the case of circuits with earth returns by arranging one thick copper wire in the centre of the bundle of conductors. The induced currents set up with this central conductor by a telephonic wire neutralise in part the effects which this latter would have upon the wires in its proximity. Messrs. Felten & Guilleaume and Messrs. Siemens & Halske overcome these inconveniences by wrapping around each insulated wire some thin metal foil, which exert a similar influence. The external sheathing of lead tends to act in the same manner. Nevertheless, the capacity of the conductors — that great enemy of cables—becomes increased rather than diminished by these devices. One of the most satisfactory solutions of the difficulty consists in making use of metallic circuits, consisting of two insulated wires twisted together the single pairs of wires being then stranded together in the cable. By this means we have the advantage of doing away with the mutual

induction without increasing capacity. Moreover, in order to diminish this latter yet more, it has been the practice latterly to make use of telephonic cables sheathed with porous insulating coverings, containing the largest possible quantity of air, it being well known that *air* has a specific conductive capacity much below that of solid di-electrics. In following out this idea, we have conductors enclosed in a paste of paper dried and compressed and strengthened by a covering of cotton. As this insulation is not costly, it may be applied in strata of considerable thickness. The double wires are then made into a cable, the bundle protected by a lead sheath, and the ends of the cable carefully paraffined to prevent the penetration of moisture. The double conductor thus compounded is found to have a capacity of ·07 of a microfarad per kilometre (0·6 of a mile). Its insulating resistance reaches to as much as 280 megohms per mile, which in practice is found more than sufficient. The cable adopted by the Metropolitan Telephone Company of New York, as also that recently employed in Milan, is constructed on this model.

Another form of cable insulated with stiffened paper owes its origin from the German firm, Felten & Guilleaume. Each circuit comprises two copper wires, separated by a strip of very stout paper, which are then twisted together along with the strip. Around the twist thus produced a second wrapping of paper is wound. A given number of circuits arranged as above are stranded together, and protected by a wrapping of cotton, and finally encased in a sheathing of lead, which prevents the access of damp. Owing to the insulating layer interposed

between the two wires, and the low inductive capacity of the paper and the air, the capacity of this cable does not exceed ·08 of a microfarad per kilometre. Some submarine telephonic cables are insulated with gutta-percha. We may mention, as an example, the telephonic line between Buenos Ayres and Monte Video, consisting of about thirty miles of cable crossing the Rio de La Plata. Another example is to be found in the telephonic lines between Paris and London. These comprise the submarine section from Dover to Calais (twenty-one miles). At this point they consist of four conductors, twisted together in pairs, so as to constitute two telephonic circuits. The lines are calculated in such a manner that the product of their capacity and their resistance should not surpass a certain limit. As the capacity and the resistance of aerial lines were known, the problem resolved itself into determining the minimum diameter of the core of the cable. These cores were first insulated with gutta-percha, and then protected by a layer of jute and sheathed with stranded iron wires, each of 7 millimetres (No. 2, B.W.G.) in diameter.

CENTRAL TELEPHONIC STATIONS.

No point is perhaps more essential to the good working of a telephonic installation for public service, than a central office suitably systematised and furnished with all the apparatus for ready and certain communication, and which will allow the employé to carry out quickly and accurately his duties. The problem of a good central station has not yet been entirely resolved: from the ex-

perience of the past we are gathering fruit for the future. The rapid development of telephony—wherever it occurs, but above all in great centres, where intellectual life works hand in hand with commerce—has brought out the fact that our central offices, if not imperfect, are at least inadequate, as they are fitted up at present, to carry on the immense daily work imposed upon them, and makes the necessity felt, at least in great cities, of providing for their improvement by all those means that progress suggests, in order that they may answer more satisfactorily to their end.

A telephonic system comprises a certain number of stations connected to lines converging towards a central office where they can be united together two by two. Telephonic administrations do not usually erect in a city more than one Central, which therefore becomes the Head of the whole service—except only in the case of some locality which is extraordinarily extensive and populous, in which case the net-work is divided into sections, each one served by a special office. These secondary stations or sub-offices are themselves connected to the main office, and, among themselves, by means of a certain number of direct lines. With this arrangement the development of the number of conductors is much less than in the case of a single office. On the other hand, by multiplying the number of sub-offices, the number of movements which have to be executed in order to place two subscribers that do not belong to the same section in communication with each other, gives rise to delay in transmission, and to an increase in the expense in the working staff. The second system is therefore not to

be recommended, except where there are several subscribers grouped in different suburban localities. If the system is aerial, the central station should be located on one of the upper floors of the building set aside for the service. On the roof is arranged a large metallic framework, somewhat in the shape of a square tower, from which start the different net-works of wires which connect to the subscribers. The conductors are prolonged with flexible telephonic cables that descend to the main pin-plug, which also forms a terminal to the cables derived from the main office. This plug allows the communication between the wire of a given subscriber to be interrupted, either for verification or to be able to make the necessary transposition demanded by the service—that is to say, to put a given subscriber in or out of communication with any other given subscriber. It also comprises the lightning arresters and the switches which serve to put the whole lines to earth when storms arise.

TELEPHONIC FRAMES AND SWITCHBOARDS.

We have already adverted to these switchboards at Chapter I. The object of these is to place before the eyes of the employé, who carries on the service, the position of each subscriber; giving him the power of being able to verify at a glance which has called him, and to execute promptly the movements necessary for placing him in communication with the correspondent called for (see Fig. 34).

SWISS SWITCHES.

We have already said that the central switchboard consists of the telephone, the indicator frame with its relative bell, and of the switch. We have already

had occasion to mention the three first pieces of apparatus; we may now direct our attention to the latter, namely, the *switch* proper. Generally speaking, the switches of telephonic switchboards are of the pin type, with some modifications. Beginning by the Swiss system: Around the walls of the switch room are arranged several of these pin-switches, each one under the care of an operator. The wires from the subscribers are connected, after having traversed their respective annunciators (or drop indicators) to the

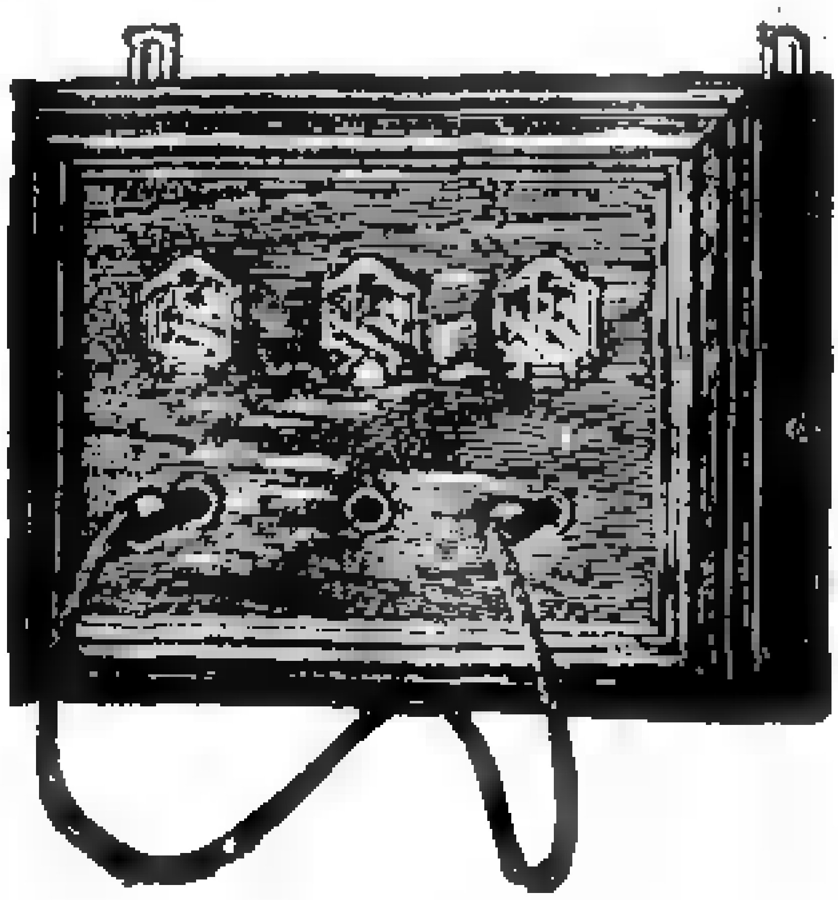

FIG. 34.

vertical bars. Each of these vertical bars is furnished with a peg which admits of its being placed in connection, or coupled up with any of the horizontal bars—one of which is taken to earth. In the normal condition, this is the place occupied by all the pegs; a second bar is connected to the magneto-generator, by means of which the operator can send the call current to the different subscribers. A third bar communicates with the telephonic station, and is exclusively for the use of the operators. The other bars are insulated, and admit of being connected up

to any or all of the lines that terminate in that office. In order that any two subscribers may be put in communication, a certain number of the bars belonging to each switch are prolonged so as to reach the other switches; and these bars bear the same colour and the same numbers as the two switches that they are destined to unite—this being done with a view to prevent, as far as possible, mistakes. Swiss

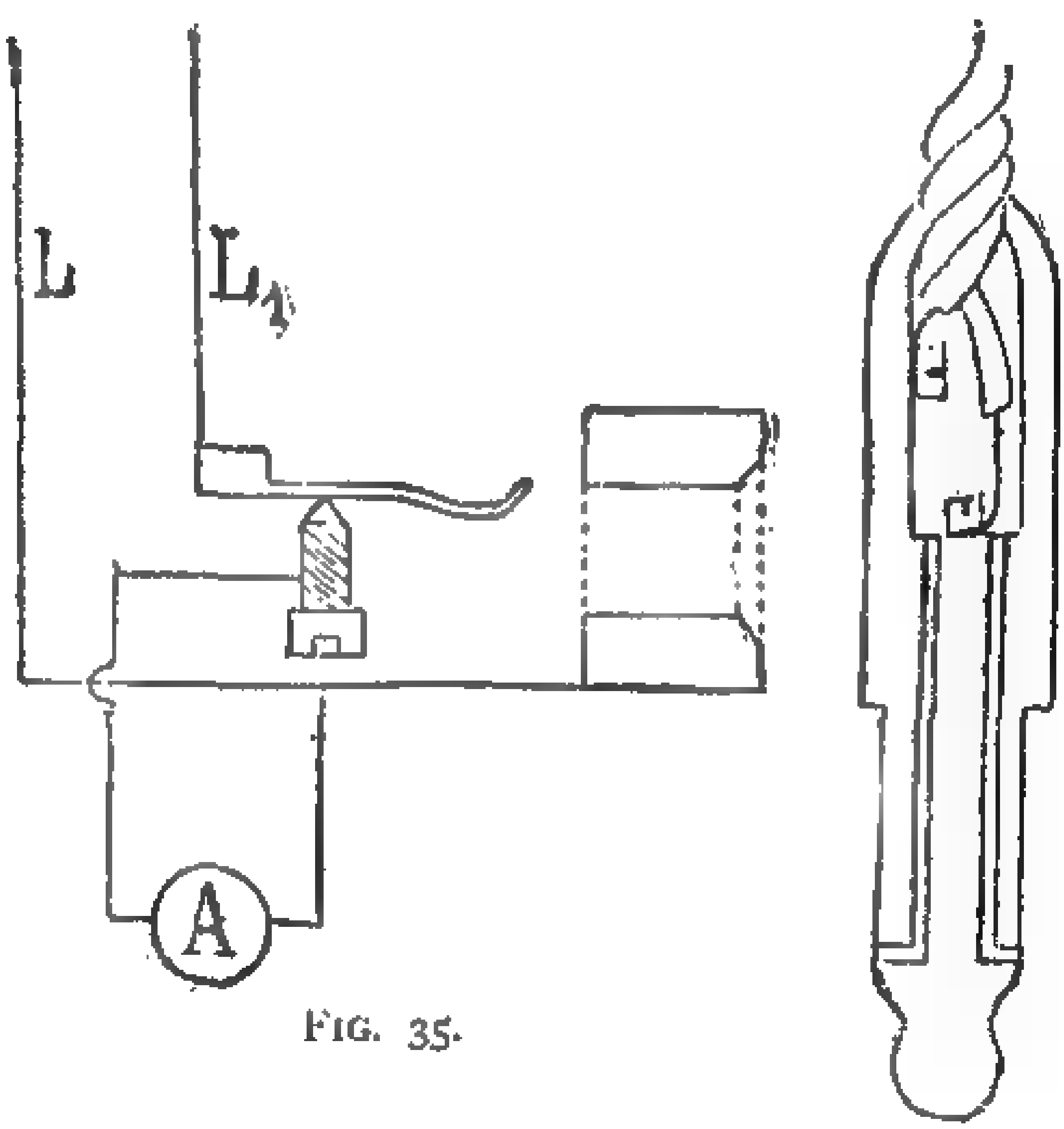

FIG. 35.

plugs and switches are of rather inconvenient dimensions. They have been, therefore, generally replaced by other switches known as *spring-jacks*. The spring-jack may be looked upon rather as a part of a switch than a complete appliance. It consists in an elastic blade connected to one of the line wires, resting usually on a moveable contact that communicates with the subscriber's annunciator. The other line

wire is also united to this annunciator, as also to the metallic lining of an orifice into which the peg can be introduced. This peg, or plug, consists in two parts, insulated the one from the other (see Fig. 35), each of which is in metallic communication with a flexible cord which terminates either on the two lines of the employé's telephone, or else to another similar peg. On introducing this latter into the switch or jack, it raises the spring-blade by means of a little knob with which the peg ends, thus bringing the line wire (L_1) into comunication with one of the extremities of the flexible cord. The other extremity, by means of the metallic lining at the mouth of the jack, remains connected up to the line L. The annunciator—which is of considerable resistance—is thus cut out of circuit.

Standard Frames for Double Wires.

In this system, the jacks, or the annunciators, are grouped together to the number of one hundred in the compartments of the upright switchboard. A given number of double-pin switches serves to connect these jacks, and are themselves connected to the switches arranged on the board. If the number of subscribers exceeds a hundred, they are coupled up on similar compartments connected among themselves by jacks and by the line wires. When it is necessary to put into communication subscribers connected to other switchboards, the operator at the board to which this subscriber belongs, tells the employé operating the board of the subscriber asked for, to connect up by means of one of the jacks. When the number of subscribers exceeds one thousand two hundred, or one thousand five hundred,

such demands become very frequent, and give rise to a number of complicated manœuvres, which increases the probability of error. This, therefore, is a central call system, that is only admissible in cases where the installation is of limited application.

MULTIPLE SWITCHBOARDS.

These were devised by Messrs. Hoskins and Wilson for use in offices overburdened with work. By means of such switchboards a single operator is in a position to connect up any two subscribers, whatever be the number of circuits. The staff required by the offices, and the time needed to establish communication, can both thus be reduced to one-half. Let us suppose that we have a net-work of single wires, each line possessing a jack on each one of the frames. In this manner the line passes successively through a series of jacks, 1, 2, 3, 4, called general jacks, which are all connected together, and thence to a last one, jack No. 5, called Individual, or Private, attached to the lower part of one of the switchboards, and having the annunciator in series with it. When a subscriber calls, the indicator-card is displayed, and the operator places in the Private jack a peg, thus placing himself in telephonic touch with the subscriber in order to receive his message. In order to carry this out, he places a second pin-switch (which is connected up to an indicator of "final message") in the general jack belonging to the subscriber called for on the switchboard, calls him, by means of his generator, and then leaves the two subscribers in consultation. Two operators suffice to work a switchboard for one hundred individual jacks.

BRANCH MULTIPLE SWITCHBOARDS.

It is found that with a Branch Multiple Switchboard, invented by Messrs. Kellog and Bouchard, a single central office can carry on the work necessary for the service of from ten thousand to fifteen thousand subscribers. This system is known as the multiple branch, by means of which each subscriber has at his disposition two bells for currents in opposite directions; the first, corresponding to one half of the subscribers, and the other to the other half. These two bells call two different operators, each one of whom controls no longer the totality of the lines, but one half only—the system, in this way, doubling the capacity of the office. In net-works of double lines, the switches can be divided up into four, or even eight groups; the combination of two wires and one earth return, with inverted currents, admit of eight different calls.

We have here rapidly passed in review all the apparatus necessary even in an important and extended telephonic installation. Our space will not permit us to go more deeply into the minutiæ of the construction and action of all these pieces of apparatus, which have now reached a very high degree of perfection. The demands of civilised life are impelling manufacturers to perfect the different appliances which are consequently undergoing changes every day—the principle, however, remaining almost the same—and any such modifications will be readily understood by the reader who has carefully perused the two preceding chapters.

CHAPTER IV.

The Installation of Long-Distance Telephonic Apparatus.

IN view of the study we have made in the last chapter of the action of telephonic instruments and their lines, it will not be necessary for us to dilate on these subjects in this section, more especially as we do not intend to include the important telephonic lines that connect city to city. In the case of setting up two stations in direct communication the one with the other (see Fig. 36), it is only necessary—after having set up the lines, poles, etc.—to connect the two upper binding-screws of the telephone with the two line wires; or, if the earth is used as a return, with one line wire and the other with the earth-plate. In the first instance, the plate belonging to the lightning arrester must be connected to earth separately; in the second instance it should be connected to the line terminal that already goes to earth.

In order that the different pieces of apparatus should be able to correspond the one with the other, we have seen that it is necessary that a central switch-board should be employed, and we have already pointed out by our sketch the mode in which it acts. We will carry these details a little farther, however, because it is only by means of an exact knowledge

of the circuits that the operator can acquire facility in setting up, and certainty in localising faults or damage. Let us study, first of all, the case of an installation with a single wire—that is to say, one line wire only—and we shall be able to follow out in detail the run of the current in such apparatus. At Fig. 37 we show the electro-mechanical arrangement, the drop indicator, and at Fig. 38 the combination of the peg-switch or pin-switch, or jack, of the single wire

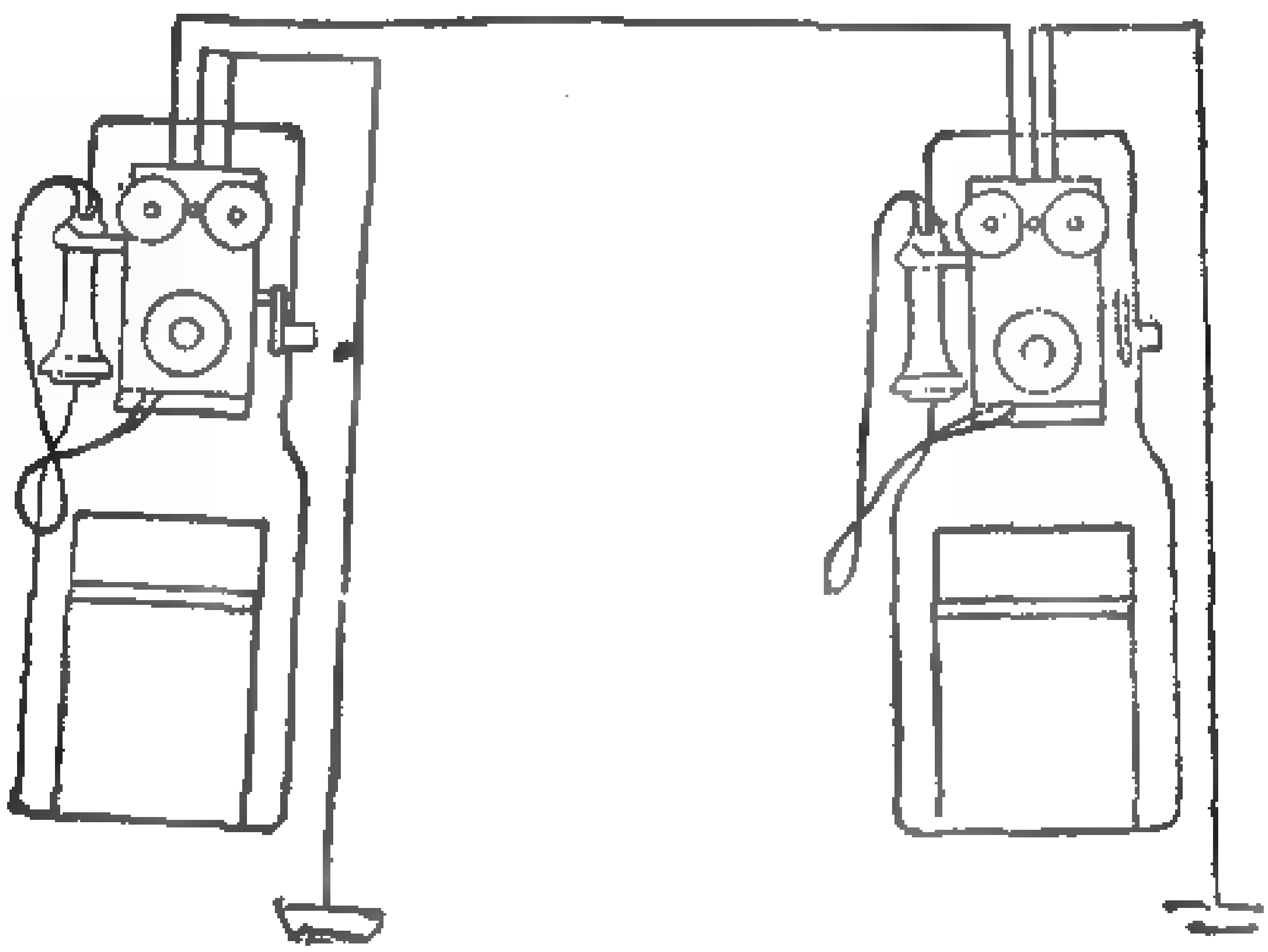

FIG. 36.

type, which, although apparently complicated, practically consists, as far as the electrical part is concerned, in an arrangement similar to that sketched at Fig. 39. When at rest the three pins, which are clearly seen at Fig. 40 (which represents the installation in its entirety), are free, for which reason a current entering either by line 1 or line 2 can only pass through the coil of the telephonic indicator, and discharge itself to earth. On falling, the flap of the

indicator establishes a contact, so that the central telephonic apparatus is put in shunt with the line traversed by the current, and can thus receive the call notice by means of its own bell. The central operator, in order to reply, must now introduce his

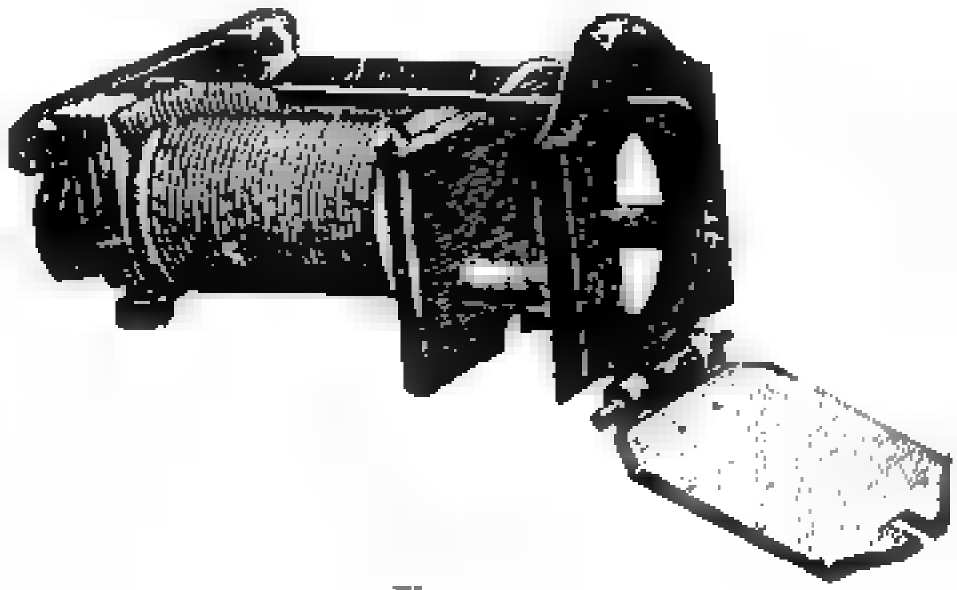

FIG. 37.

own pin—which is entirely metallic—in the hole corresponding to the line which has called him. It is easily seen how direct communication is thus established with the other telephone—the useless resistance of the coil of the indicator being at the same time cut out. If the central telephone is in charge with the duty of placing the two lateral stations in direct corre-

FIG. 38.

spondence, it will be necessary to introduce into the two corresponding holes the two pegs that are shown below the apparatus. One of these is wholly metallic, while the other has, along a certain portion of its length, an insulating sheath that separates it from

the metallic lining of the jack, which is in direct communication with the line. It will be observed

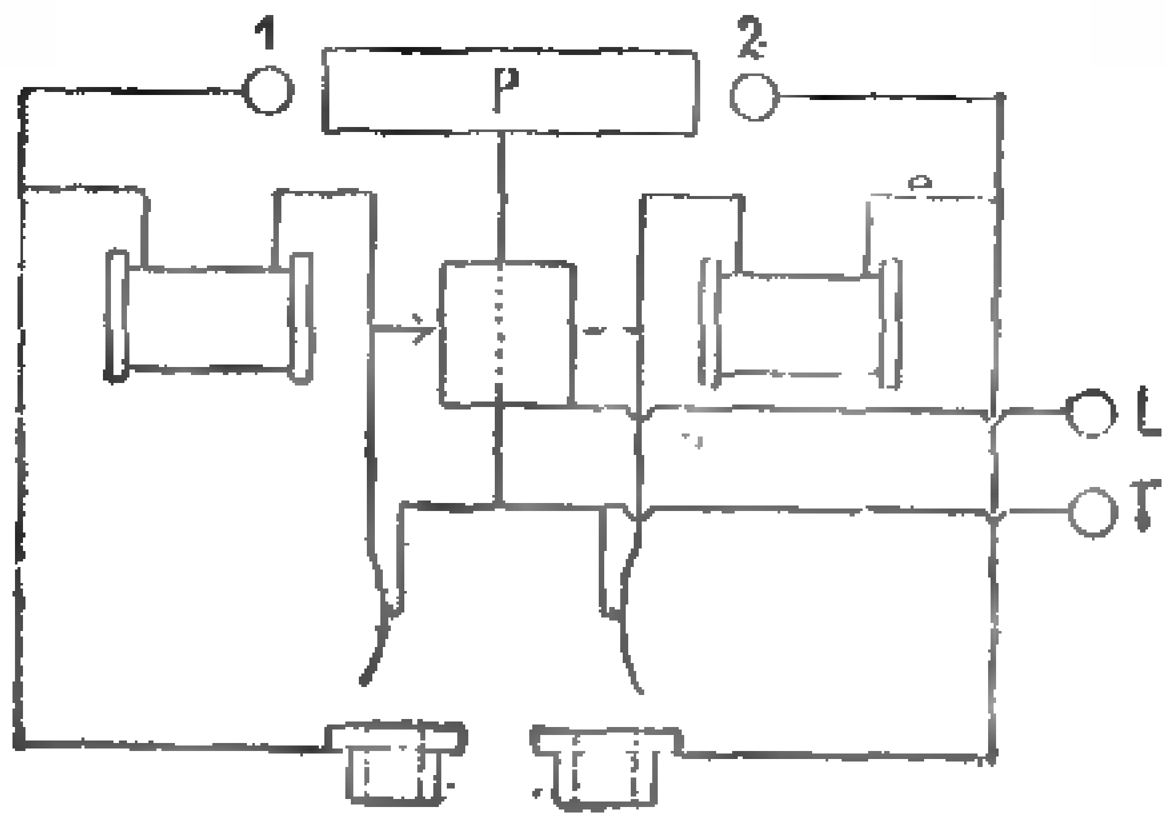

FIG. 39.

that there remains included in the circuit an indicator which may be used to give notice of the termination of the conversation. It will suffice for this purpose that one of the side stations, when finished, should

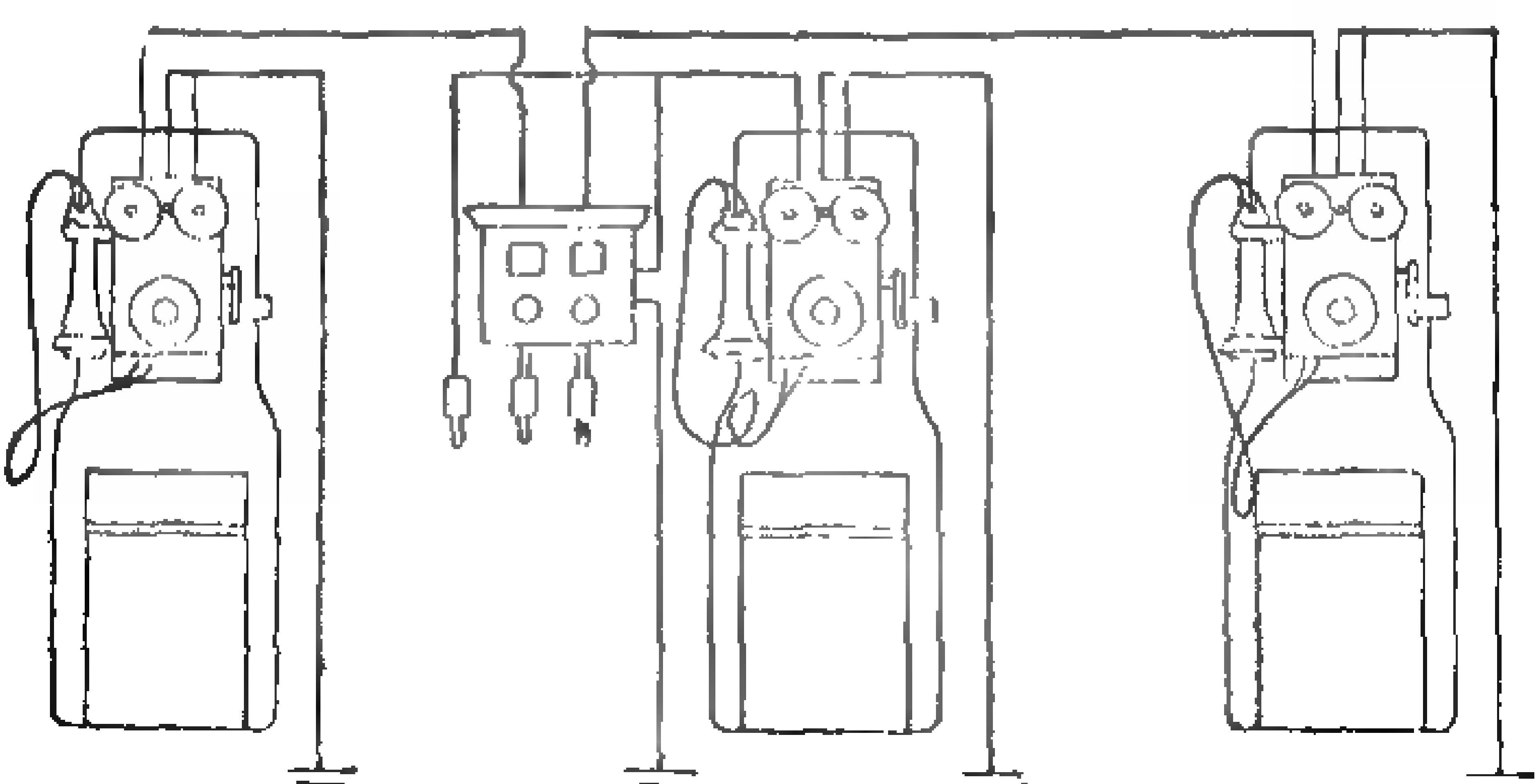

FIG. 40.

transmit a current in the line that should throw into action the coil from the bell of the central one.

It often happens that it is necessary to provide the central instrument with a continuously ringing bell, that should insistently warn the operator at that point of the call for operation, especially in those cases where the operator, having to attend to many places, may be absent from the telephone. Our Fig. 41 represents the central station in its entirety, while Fig. 42 is a diagram of the internal connections of one of smaller dimensions. In this case the pins of

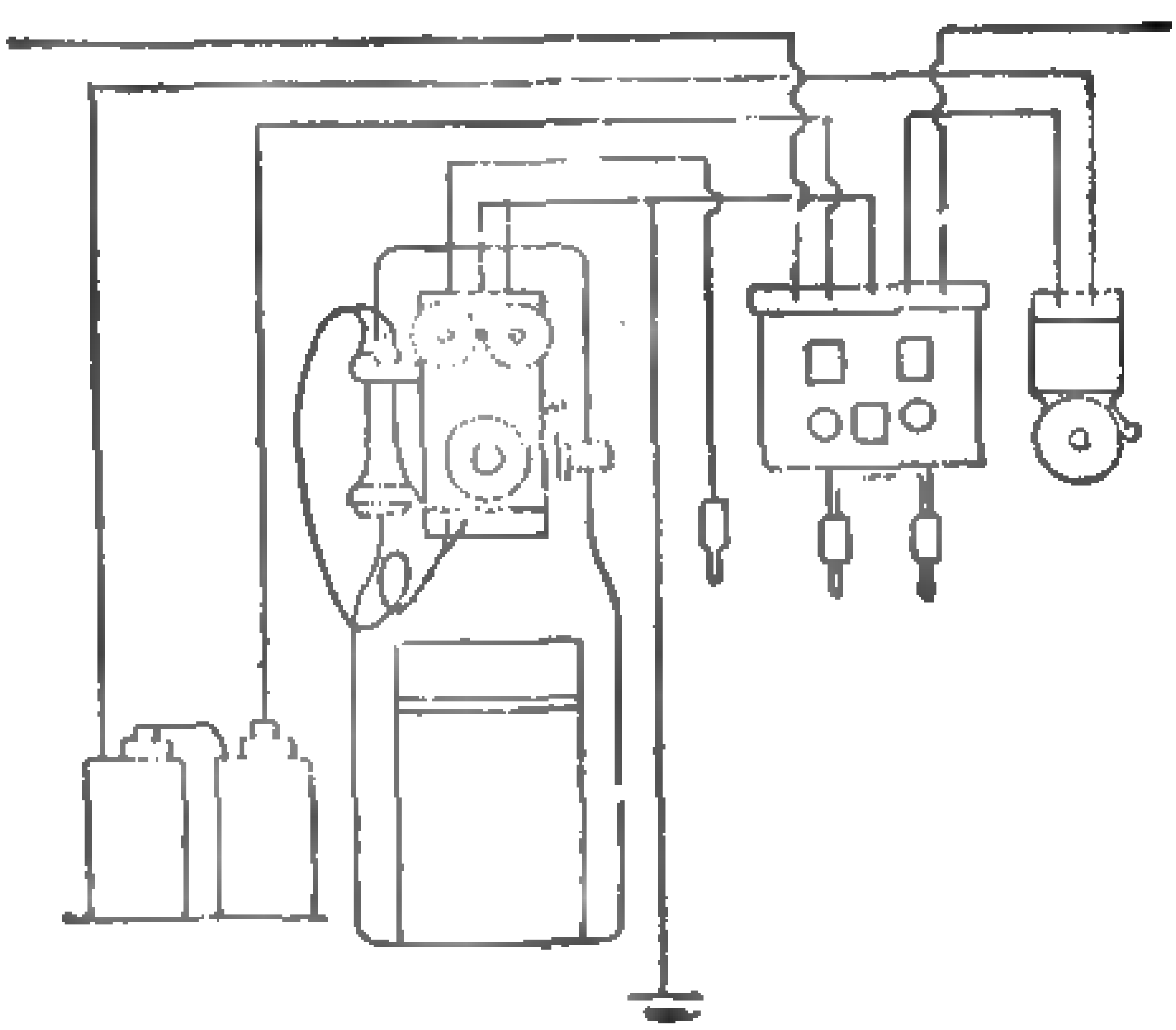

FIG. 41.

the jack only serve to cut out the coils of the indicator, and to place the lines in direct communication. In order to signal the termination of the conversation, a special indicator, C, is placed in series with the two pins fitted at the central station. The continuously-ringing bell is, of course, actuated by a separate battery, and goes on ringing until the operator in attendance raises all the flaps of the indicator.

We may now pass on to consider installations using two wires—that is to say, those in which the circuit is entirely metallic. We have already pointed out the cases in which such arrangements are necessary; and these call for the use of central switchboards differing from those just considered. When using jacks, like those shown at Fig. 38, it is necessary to have on the central board twice the number of jacks that there are telephones to which they refer; and the plan, which we give at Fig. 43, gives us the

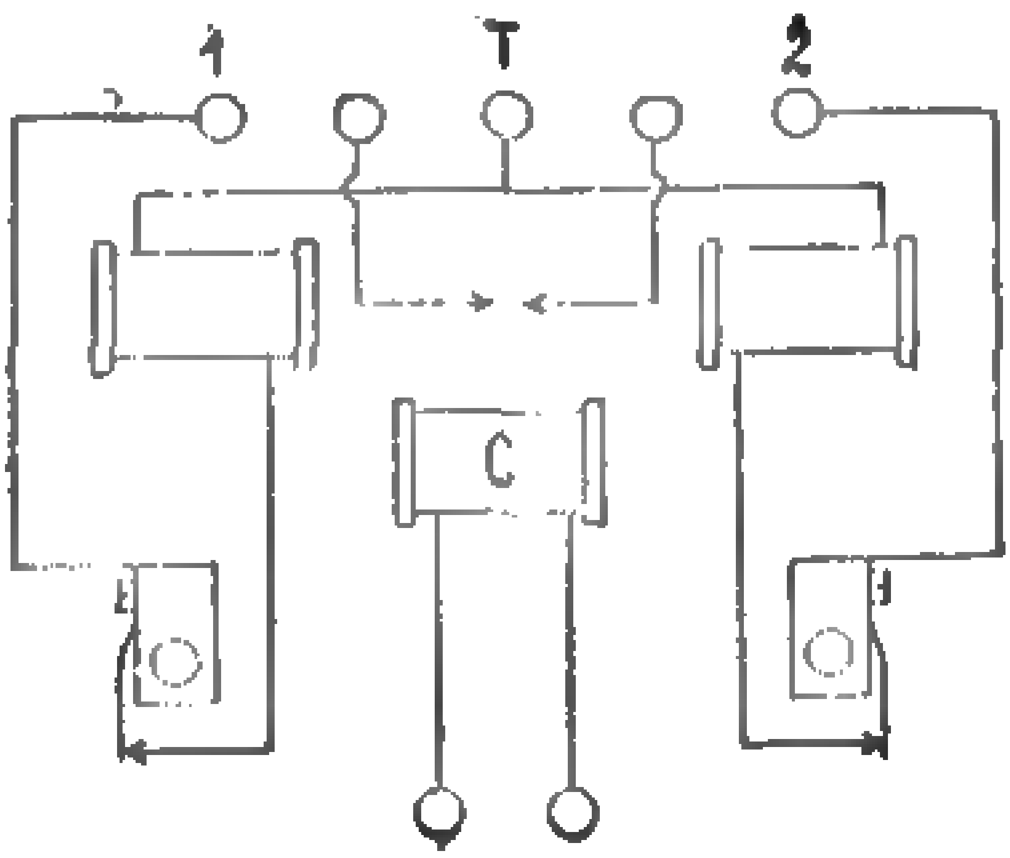

FIG. 42.

reason for this. We must premise that now the pegs are no longer in one piece, but composed of two insulated portions, precisely like those figured in the previous chapter, at our illustration, Fig. 35. Communication between one of the lateral telephones and the central one is effected by introducing the peg of this latter in the *upper* line of the jack. Communication between two side stations is made by using the two pegs fitted *under* the frame, and which are placed in communication with the two telephones

to be joined up—but one in the upper line and the other in the lower line of the jack. In this way, one of the indicator coils showing "End of message," is included in the circuit. Our Fig. 44 shows the arrangement of the central station used in this instance. A single line of jacks may be employed instead, provided the special form shown in Fig. 45 be made use of. The two pegs fitted below the frame are constructed as previously described; but

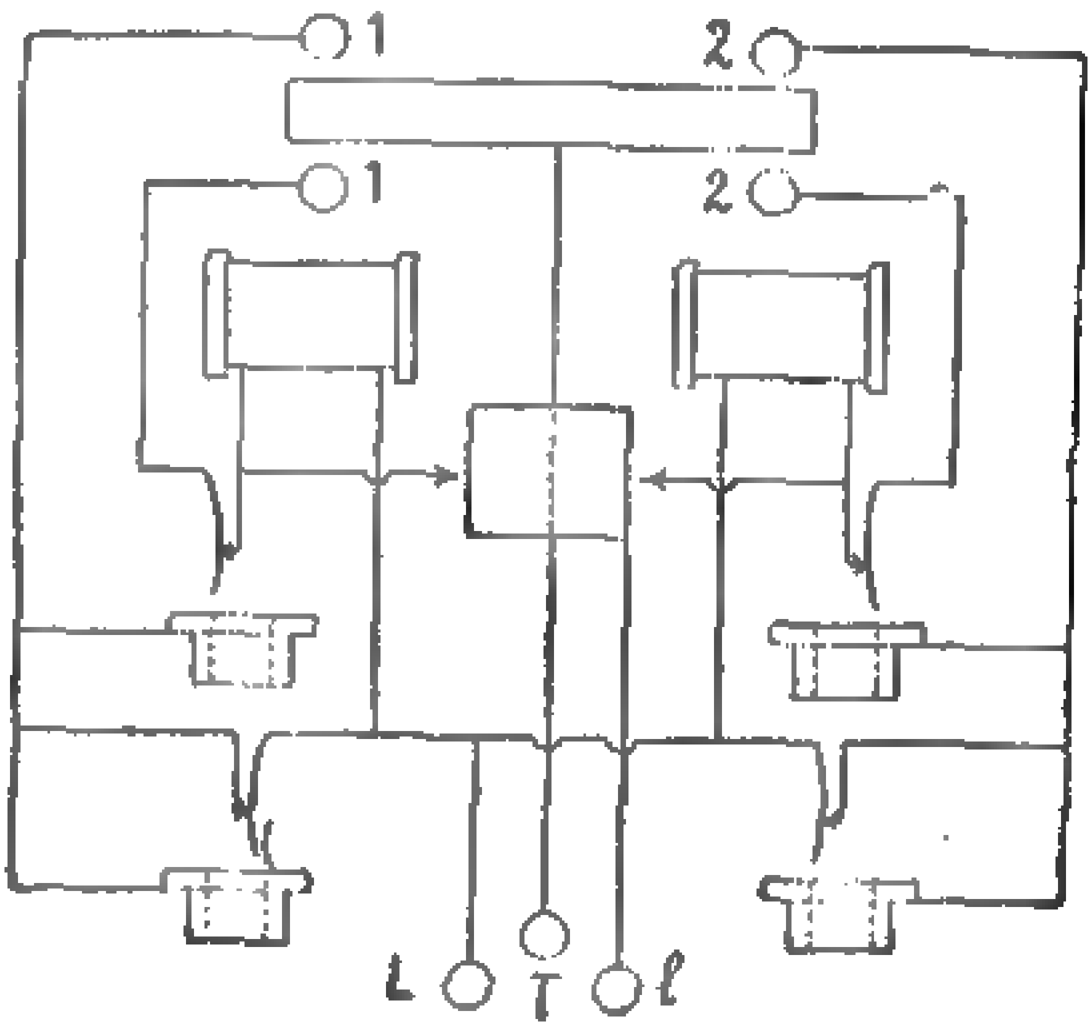

FIG. 43.

they differ, inasmuch as one terminates as usual in a little metal ball, while the other ends in a pear-shaped prominence. This projection serves to connect, electrically, two parts of the jack, that in their normal position are insulated the one from the other, as may be clearly seen in our diagram. If the plan of the internal communications of this smaller Central Station be carefully examined (see Fig. 46), it will be noticed that in that jack in which the pear-shaped peg is

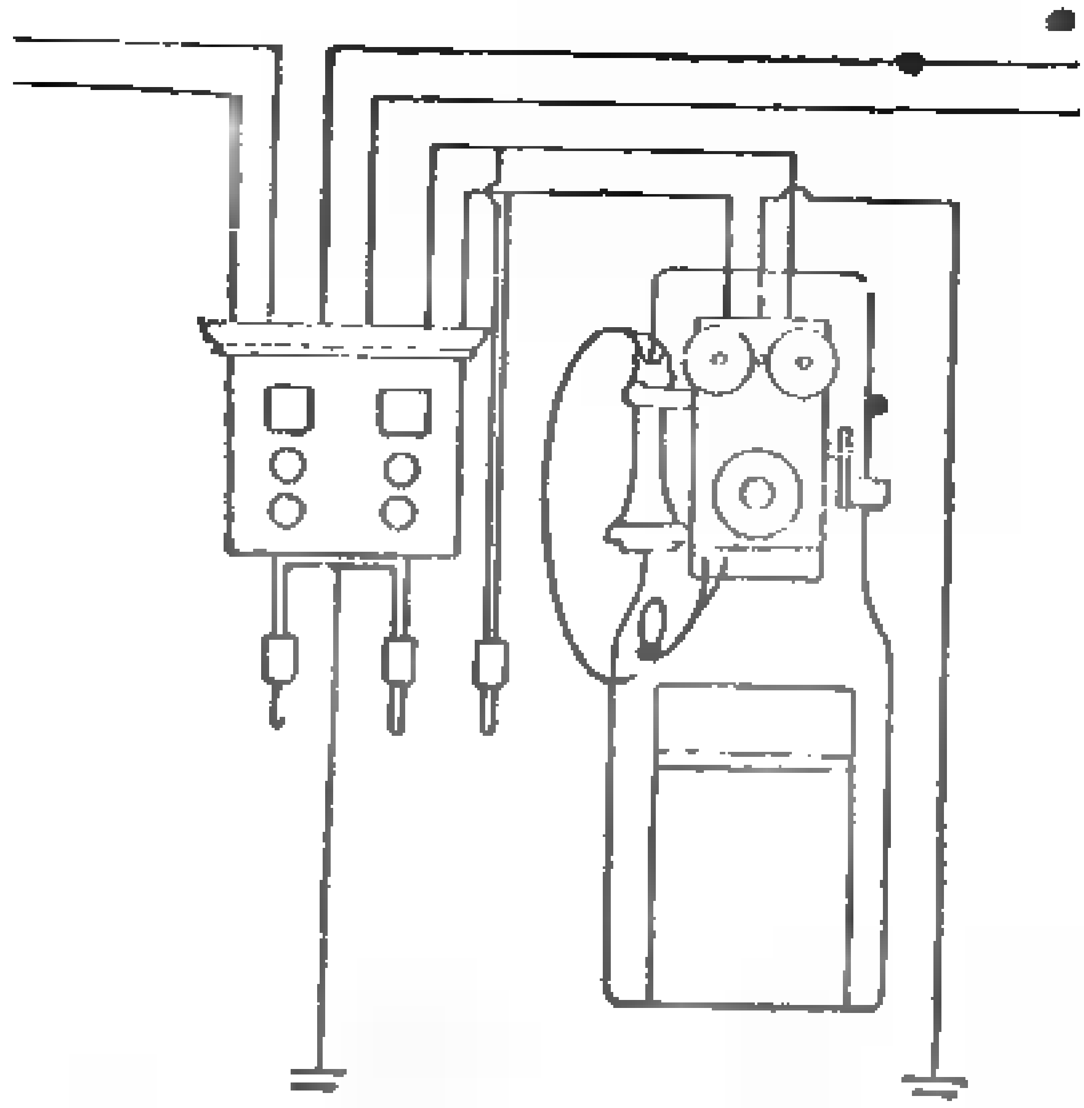

FIG. 44.

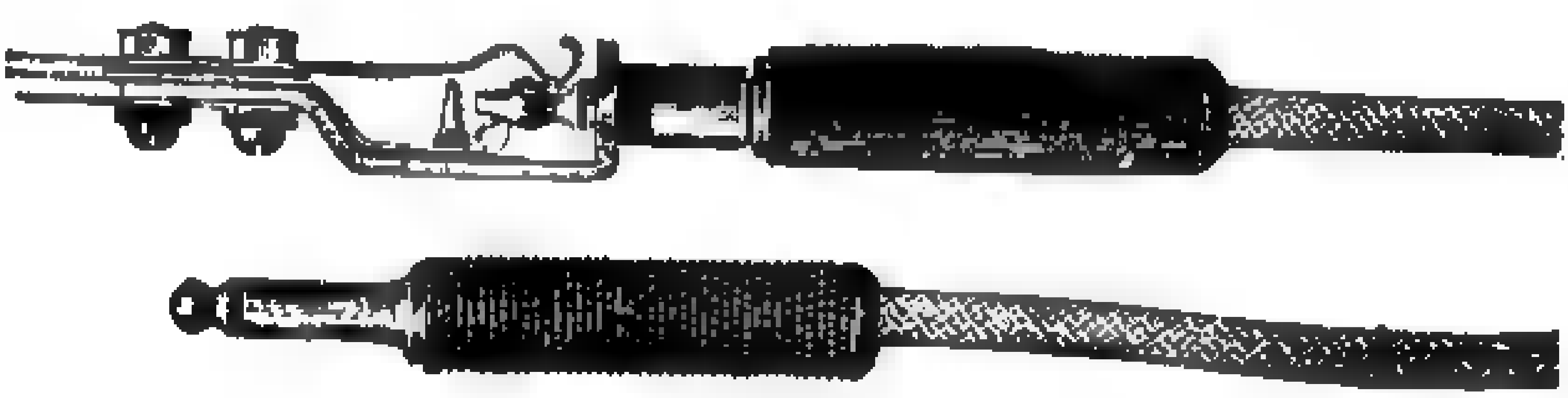

FIG. 45.

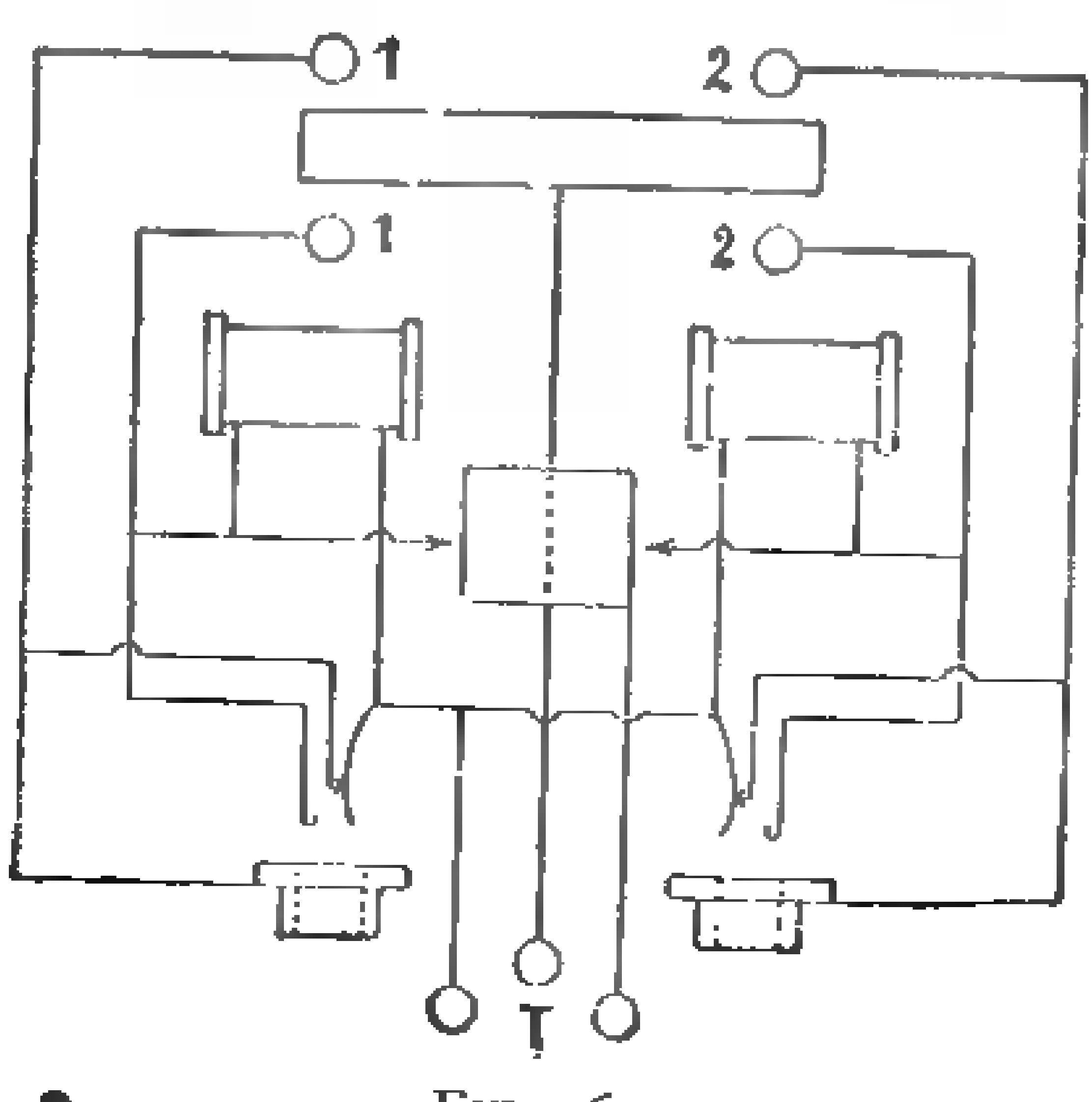

FIG. 46.

placed, is included, as a consequence of the communication that this latter automatically brings about, an indicator which serves to signal "End of message." By this means, both the telephonic switchboard and the operations to be carried out are considerably simplified.

Perego's Safety Telephonic Transformer.

When telephonic lines are supported on the same posts that sustain other lines carrying electricity of high potential, it is necessary to take precautions to ensure safety and to avoid any danger to those making use of the apparatus, in case of contact between the telephonic wires and the others. In consequence of the multiplicity of generating stations, installations of this kind are frequently required, since the generating stations must of necessity be able to correspond certainly and readily with their works, etc., in order to be able to satisfy the demands of the consumers. The electrical energy sent out by these stations is always of high potential; and for the sake of economy, the wires carrying this energy and those which are destined for telephonic use are stretched between the same poles. Hence it may happen that very heavy currents, even dangerous ones, may leak, or otherwise be set up in the telephonic wires and apparatus, imperilling any one who might at that moment be in contact with them. Special telephones are to be found in the market which are insulated, the whole electrical portion being enclosed in a concealed case, while the sounds that are transmitted or received, the movements of the hook and of the devices for calling, are com-

municated respectively by means of a tube, levers and belts being insulated in such a manner that the user cannot receive any dangerous shock.

Perego has resolved this problem by his system in another manner: he has constructed an accessory apparatus which can be applied to the ordinary type of telephone—and this is convenient both from an economical and technical point of view. His apparatus consists in a special telephonic transformer, the coils of which, consisting of a primary and a secondary circuit, are each enclosed in metallic boxes placed in good communication to earth. The primary is naturally connected up to the telephonic lines, while the secondary is in connection with the telephonic apparatus, which may be of any one of the types usually found in commerce. The ratio of transformation in these apparatus is 1 to 1, or 1 to 3, according to the necessities of the case; but no dangerous potential can be induced in the secondary, because the iron that constitutes the magnetic circuit becomes saturated at a tension which does not exceed 150 to 200 volts. Besides this, the primary circuit is protected by safety fuses, by comb dischargers, and also by condensers, so that it is practically impossible that the primary should reach any high tension. But even in the case that the fuses should fail to "blow," or that the insulation should give way, no harm would accrue to the secondary circuit, because the metallic box already referred to would allow the immediate discharge to earth.

We may, in passing, remark that this form of safety-transformer may be also employed to protect *telegraphic* apparatus from any danger arising from

high contact with high tension lines or from atmospheric electrical discharges, when a polarized relay is used. Fig. 47 represents a small frame on which are mounted the transformer, lightning conductor, and the interrupter taken to earth. On the sides are

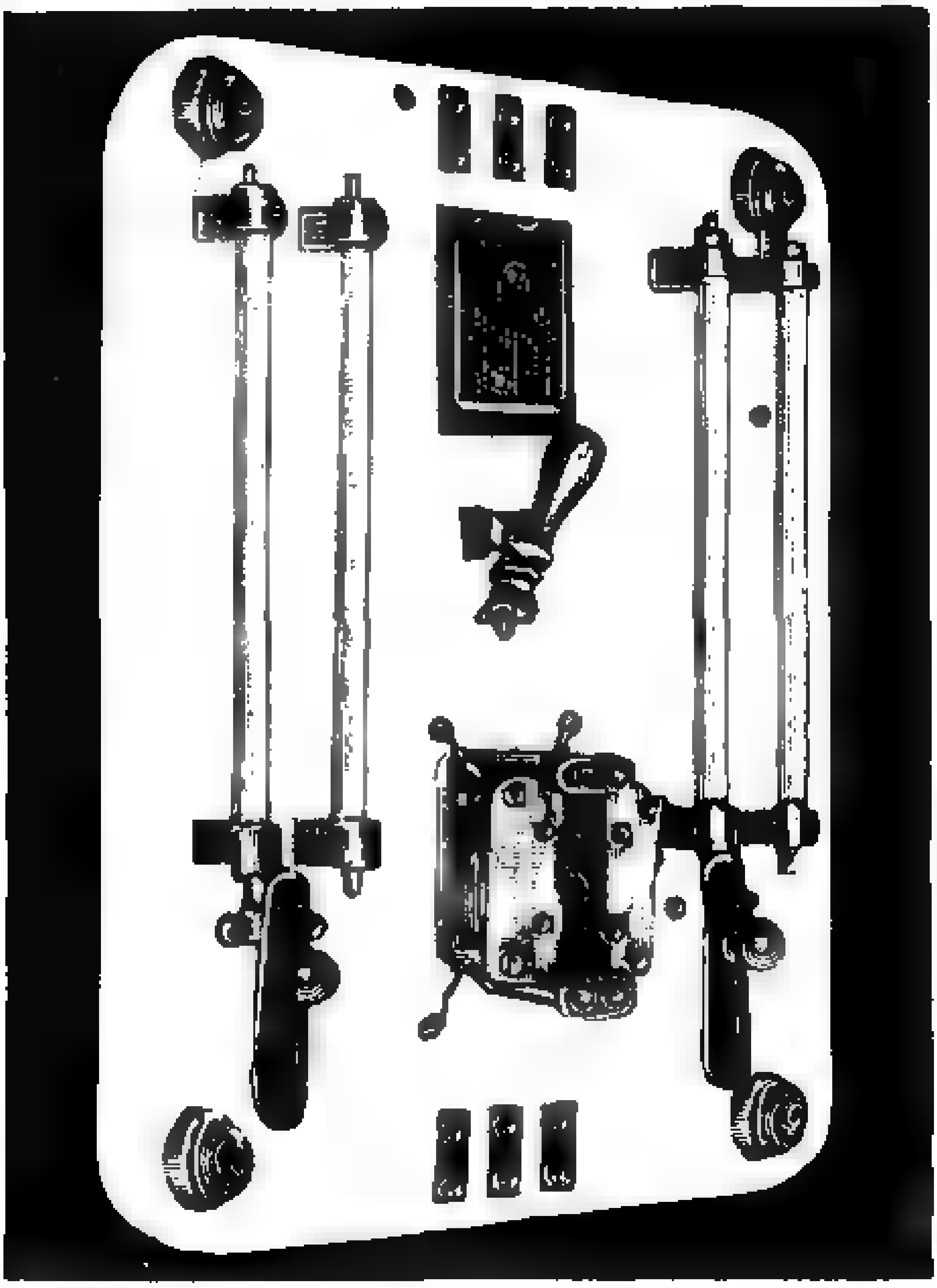

FIG. 47.

shown two pairs of safety fuses, with a switch for each pair, to facilitate exchanges when, after a discharge, it is desirable not to interrupt communication. The primary and the secondary windings can be easily exchanged or replaced, and their perfect insulation ensures their proper working, and is not

likely to set up induction if the circuits are frequently earthed. By means of such a transformer it is also permissible to put into communication several telephonic stations, making use of ordinary instruments (as in the case of a central telephonic office), by placing at the extremities of the lines on which some dangerous contact may arise, the primary; while the

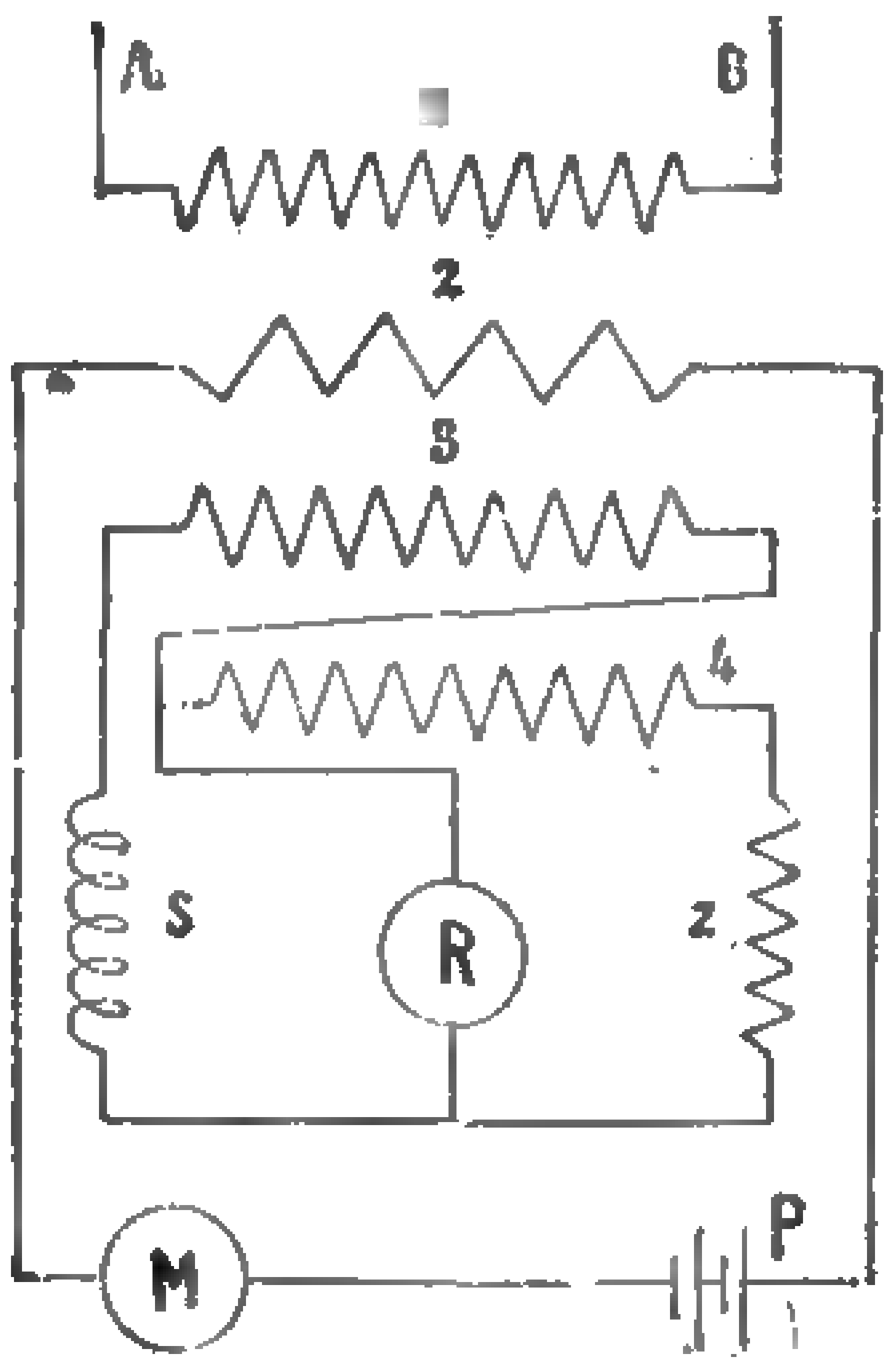

FIG. 48.

secondary may, by means of the smaller central offices, be placed in communication with each of the corresponding stations.

ELIMINATING INDUCTION.

Perego has also devised apparatus for eliminating induction in telephones and in telephony on telegraphic lines. Let A B (Fig. 48) be the line to which it

is desired to apply the telephonic apparatus, a shunt primary, 1, is connected to its two extremities. This constitutes the primary of the telephonic transformer, consisting of a secondary winding, 2, made of a few turns of coarse wire connected in series to a microphone, M, and the battery, P. This secondary acts like the ordinary induction coil placed in the usual telephones—that is to say, it serves to induce in the primary, and consequently on the line, electrical currents corresponding to the sonorous waves received by the microphone. On the transformer there are two other spirals, 3 and 4, consisting of an equal number of turns and having the same resistance; these are joined together and also to an ohmic resistance, Z, as also with the self-induction coil, S, and the telephonic receiver, R, as shown in the diagram. The ohmic resistance, Z, and the inductive one, S, are so arranged as to be equal to one another in value, for currents of low frequency (25–60 periods per second), which are the currents usually employed for signalling, for telegraphy, and induction set up in parallel circuits used for the transmission of electrical energy, etc.

From this it will be seen that with such frequencies there will be a tendency to the passage of two currents in the receiver, R; and as these are equal and contrary, they will annul one another. This is due to the fact that the electro-motive forces induced in the circuits 3 and 4 are at each instant equal, because the circuits consist in an equal number of turns, their resistance being also equal, the currents which will circulate through them will be equal likewise. Hence, currents which would tend to disturb the telephonic

reception are eliminated. Telephonic currents have a much higher frequency (about 600 periods per second), and these are intercepted by the self-induction coil S, and, consequently, only the currents set up in the coil 4 will pass into the receiver R, because the resistance then maintains its value whatever be the frequency of the current.

When it is desired to eliminate the induction or

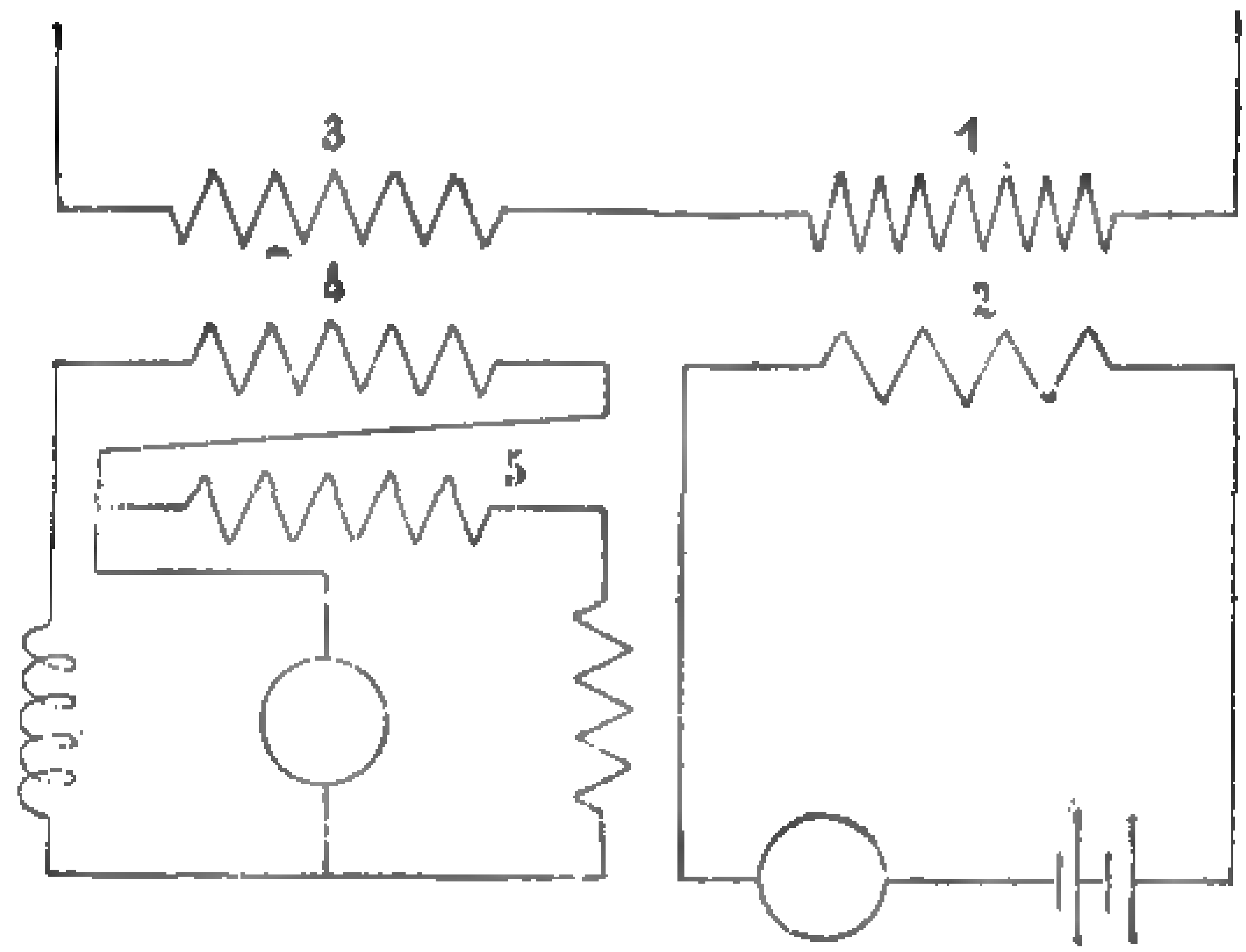

FIG. 49.

local currents in a telephone fitted on a line already serving for telegraphic or other signalling correspondence, the ordinary induction coil may be replaced by the aforementioned transformer, or the circuit may be arranged as shown in our plan (Fig. 49). Instead of placing the telephonic receiver in series with the winding, No. 1, of the fine wire of the induction coil, the primary, 3, of a little transformer, over which are wound the coils 4 and 5, in series with

the self-induction and with the ohmic resistance, which will then act as previously described. For calls, the ordinary magneto-generator may be employed, when it is a matter only of doing away with the induction, but if it is desired to apply the telephone to an existing telegraphic or signalling circuit, it will be necessary to make use of an electric "Buzzer," in order not to derange telegraphic transmission.

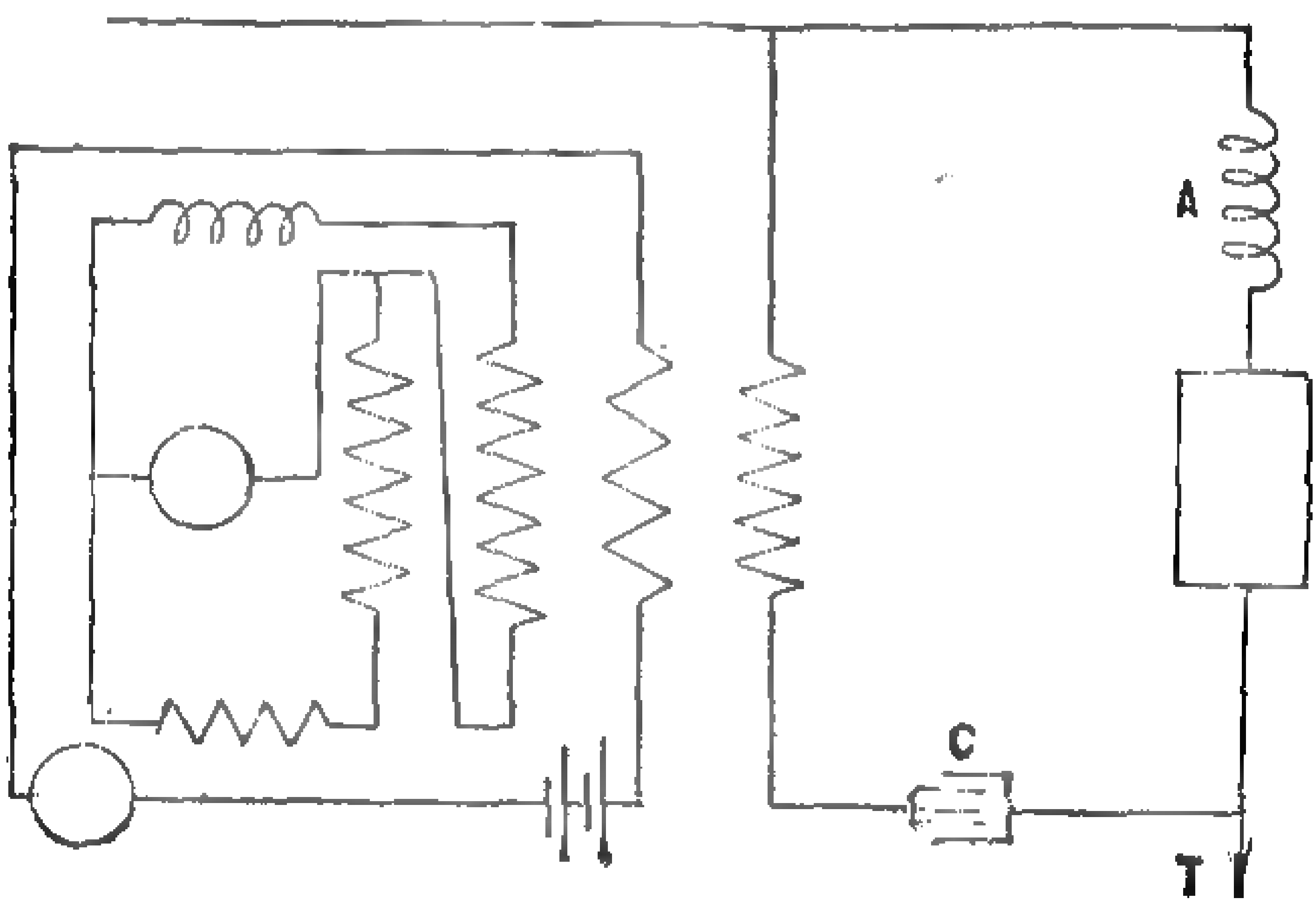

FIG. 50.

The plan given at Fig. 50 shows the arrangement that may be adopted for simultaneous telegraphy and telephony: L is the line; A is a re-actance coil in series with the telegraphic frame, the purpose of which is to prevent the telephonic currents going to earth; T C is the condenser in series with the primary of the telephonic transformer, which prevents the telegraphic currents going to earth, while it favours

the passage of those belonging to the telephone. The disposition of the secondary and the other portions is identical with that already described. If the telephone transformer above described be properly constructed according to the well-known laws of induction, and if it be properly fitted with safety fuses, it will be found to unite in a single piece of apparatus all the qualities required for perfect combined telephonic and telegraphic service, even in those cases in which the telephonic wires are running parallel to others destined to carry electrical energy, and even when the returns are effected through earth.

CHAPTER V.

Failures and Repairs.

ONE of the most frequent causes of the failures which occur in electrical installations generally, and therefore also in those connected with electric bells, is doubtless that usually called *leakage*—that is to say, a small and continuous shunting off of current that occurs either directly or indirectly between the two poles of the source of electricity. In the case under consideration, if immediate attention be not given to remedying this defect, the battery goes on exhausting itself until it becomes totally inefficient. This loss, or leakage of current, may take place either directly between the two wires starting from the poles of the battery being in contact with one another at some point where the insulating covering is insufficient, or it may take place in consequence of a damp wall or a gas-pipe, or, in a word, in anything which brings about defective insulation. If the loss of current occurs between the two wires that lead to the push, when this leakage acquires a certain importance the bell will ring of its own accord until the battery is completely exhausted. Direct leakage between the two poles of the battery is certainly the most injurious, because such a leakage, without making any warning noise, will ruin an entire battery of cells, and it then requires all

the skill of a practised workman to prevent more damage by effecting an immediate remedy. The localisation of a leak in an extended installation is generally a long and tedious operation, requiring a certain amount of ability and, above all, a great deal of patience for its determination.

When, in a set of electric bells, the battery is found to lose strength daily without there being any external indication of damage, the bells still ringing, but more weakly, the cause may be readily imagined. The first thing to ascertain is whether there be merely leakage or whether the battery itself is short-circuited. An indication of this may be had on observation of the battery, which, if there be leakage, would give off a disagreeable smell, due to the liberation of ammonia; the zinc rods will become very thin, fragile, and covered with little bubbles of hydrogen; the porous cell, if turned upside down, would allow much water to drip from it. However, these symptoms would not suffice to give certainty of the existence of leakage since they are common to an old or badly-kept battery, for which reason it is necessary to make a test with special apparatus, such as a galvanometer or other similar detector. Such instruments, known as linesmen's detectors,* can be obtained almost everywhere, or can be substituted by an ordinary compass around which a few turns of insulated copper wire are wound, above and below the magnetic needle. It is true that, taking advan-

* The construction of a linesman's detector, at the cost of a few pence, is fully described, with detailed working drawings, in the new edition of "The Amateur Electrician's Workshop," price 2s. 6d. net.

tage of the great sensibility of the tongue to the weakest currents of electricity, we may use this as a means of testing for such defects, but we think that an empiric means of this kind, not too agreeable to him who has to employ it, is not to be recommended, when expressly constructed apparatus, as the galvanometer, can be had so cheaply.

In testing, the detector should be put in series with one of the lines, when, if there is a leak, the needle will be deflected more or less strongly according to the gravity of the leakage, as shown in Fig. 51.

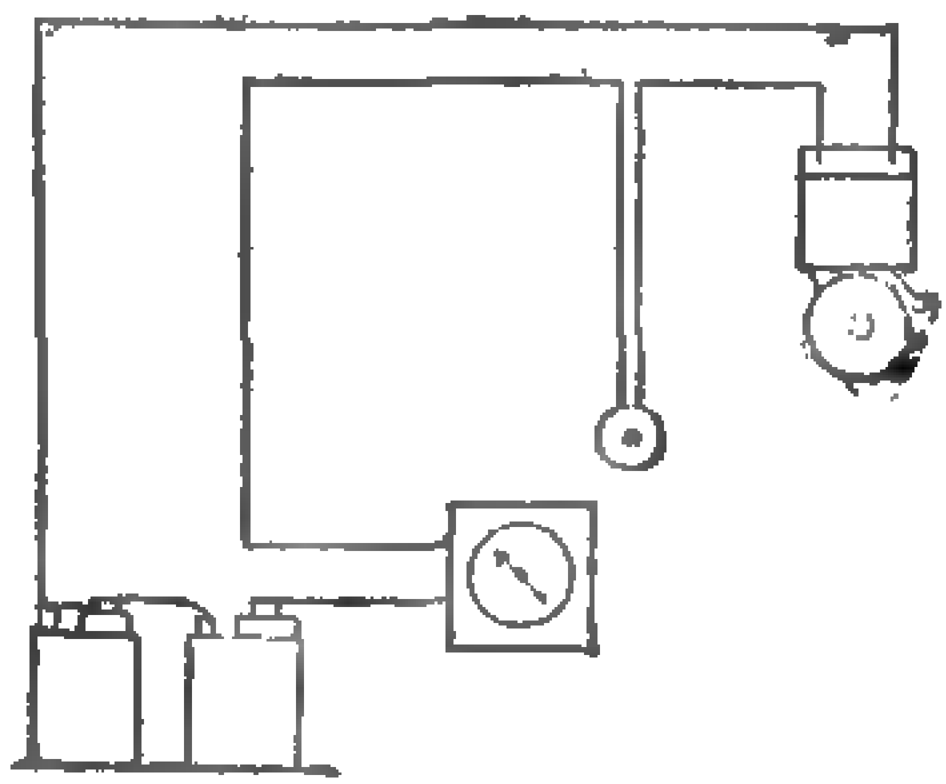

FIG. 51.

Having ascertained that the defect exists, it must now be localised, and, beginning at the battery, the two line wires must be carefully examined along their whole length, to ascertain whether there be at any point defects in insulation, noticing whether any joint be bared, and especially along those wires that pass in the neighbourhood of walls, as it is at such points that injury usually occurs. Special care must be given to those wires that run alongside *damp* walls or metallic partitions, noticing whether the staples that support the wires have in any manner damaged

their covering. If this examination be carefully carried out, and every little defect as carefully remedied, it will generally be found that the whole run will work as well as it did originally.

Sometimes, notwithstanding every care, the point of injury will escape observation, especially in the case of very extensive installations, and in the circumstances it will be necessary to localise the fault by sub-dividing the trials.

Leaving the detector in circuit, the operator will begin by detaching the wires from the bell, and proceeding thence towards the battery, at the most suspicious points, he will cut the line wires until he finds that the leakage ceases. This may be ascertained by noticing that the deflection of the detector is practically the same as it would be if connected up directly to the battery. From this may be deduced that the leakage occurs at that portion of the wire which has been last cut. When the wiring is one having several shunt circuits, either to the pushes or to bells, it will be necessary to detach these from the principal conductors (main lines), thus giving the workman the power of ascertaining whether the damage exists in the former or in the latter.

Should the run be a very complicated one, it will be found convenient, nay, even necessary, not only to divide it up into several portions, but to test these separately by means of auxiliary batteries.

If it has been ascertained that the leak occurs in a lead-sheathed cable, either between the two conductors themselves or to earth, the localisation of the fault is so difficult that it is more convenient, if the

said cable be not too long, to change it altogether. Should it be desired, however, to attempt such a localisation, a circuit must be established, as shown in our sketch (Fig. 52). The extremity of one of the wires of the cable (supposing this to be of two wires only) are joined together by a slider, *a b*, the length of which should be a sub-multiple of that of the cable, and should have considerable resistance.

On this slide is arranged (in shunt) a very sensitive detector, and a battery is then connected up to the second wire of the cable and to the slide. This

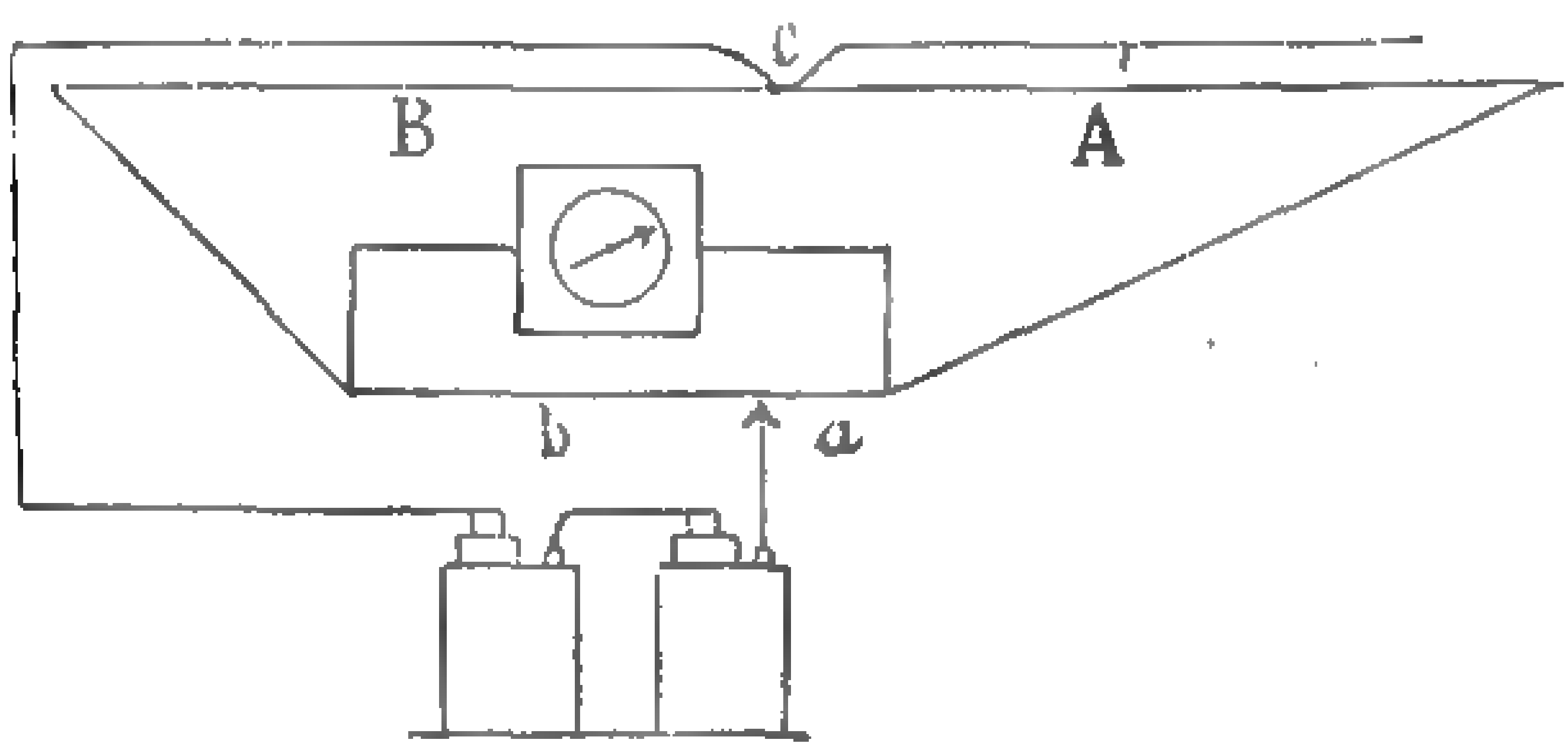

FIG. 52.

constitutes a kind of Wheatstone's bridge, and by this means we shall get electrical equilibrium, as shown by the needle of the galvanometer, when the slide is divided into two parts, *a b*, by the movable contact, proportionate to the parts, A B, in which the cable is divided at the point of short-circuit C. The variable resistance of this contact has no influence on the result, as it is not on one side of the bridge, but across the diagonal. In reckoning the point of short circuit, we must allow for the resistance of the wires that join the slide to the cable. If the short circuit

be to earth, it can be localised by arranging the circuit as sketched at Fig. 53.

The quantity of current flowing, and, hence, the deflection of the galvanometer, will become greater, as, in sliding the wire on the leaden sheathing, we approach to the point where the fault or contact C is located. As the resistance of this latter may vary from one moment to another, it will be advisable to make a series of trials and to take the average, before cutting the cable. We will not enlarge farther on this point, because these trials, which fortunately are

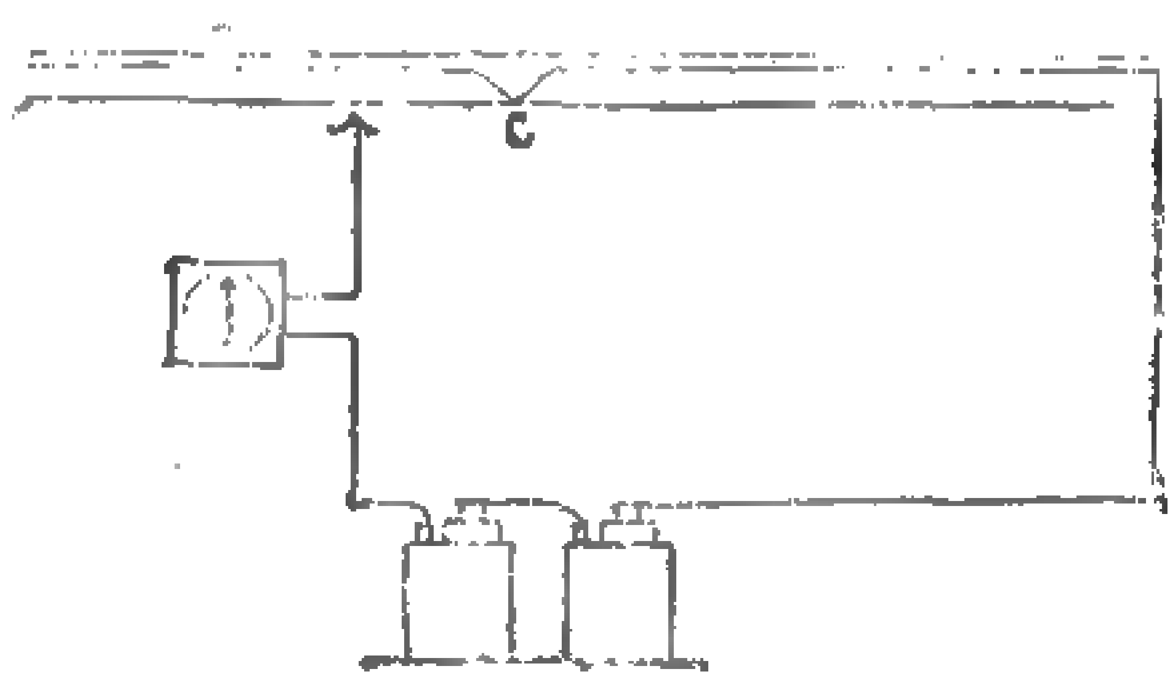

FIG. 53.

not often required, demand good apparatus and a clear conception of electrical phenomena, failing which, it is better *not* to attempt anything. Besides this, practice and good sense on the part of the operator will enable him to trace up any such short circuits far better than any stereotyped advice we can give.

With regard to other defects and their repairs, little need be said, as they are usually of the simplest nature, in the grasp of anyone, because they are generally dependent on badly-made joints, breakages in the wire, defective connection, or other things of little account.

We will rather give a little space to the consideration of repairs to faults occurring in micro-telephonic apparatus, premising our remarks with the advice that this delicate portion of work should be relegated to an operator who is accustomed to these instruments. If an interruption takes place in the ringing of the bell connected to the telephone, the first thing to ascertain is, whether the battery be in good order; then, in order to be assured that the bell itself is working properly, it should be tried directly on its own battery. If the bell and the battery are found to be in good condition, and yet when set up in their place they do not work, it would be necessary to examine the contacts in the push, its screws, the terminals, and the internal screws that hold down the springs: it often happens that the mere tightening-up of a screw or cleaning the contacts with a bit of emery-paper will suffice to put all right.

A weakening in the transmission of the voice may depend as much upon the battery being in bad order as from the receiver having become deranged. To remedy these defects, in the first case, it would be necessary to re-charge or change the battery; and in the second place, it will be enough to regulate the central screw at the back of the receiving telephone, thus throwing the membrane or diaphragm nearer to, or farther from, the magnet, as circumstances may require.

The diaphragm should always be perfectly flat, and if by any chance it has become dented or buckled, it must be changed. If speech be entirely interrupted, it is a sign of the breakage of one of the wires of the flexible cord. In order to ascertain this, the binding

screw of the carbon microphone should be connected up by a piece of wire to the terminal of the line wire, when, on placing the receiver to the ear and tapping lightly with the finger on the microphone or its disc, the sound ought to be heard in the receiver; if not, it is a sign either that one of the wires of the flexible cord is broken, or that some screw that should hold it is spoiled or loose. It occasionally happens that the defects we have just mentioned are caused by warping of the wood in the framework of the apparatus, which may be brought about as much by damp as by excessive drought. In such a case, it would be necessary to dismount and put together the telephone completely, rectifying or replacing the defective portion.

The disagreeable sizzling sounds that are sometimes heard in the telephone may be due either to bad contacts in joining the wire, or to the wires not being well gripped in or under the binding screws of the telephone. They may also be caused by defective insulation in the installation, or by the battery being used conjointly for an electric-bell circuit, or, lastly, by induction set up through neighbouring wires. For this reason, when it is necessary to erect aerial telephonic lines in proximity of telegraphic lines, or of those destined for the transmission of power, in order to avoid these disturbing induction currents, it would be necessary to use a go-and-return wire instead of making use of [illegible] earth return. By this means, in each of these wires, an induction current of equal value, but in opposite directions, will be set up, which, therefore, will annul one another.

CHAPTER VI.

The Erection of Lightning Conductors.

WHEN electric discharge takes place between an electrified cloud and the earth, lightning and thunder occur; the latter being noisy in proportion to the neighbourhood of echoing hills, and the latter feared and terrible in its effects in proportion to the quantity of electricity passing. Human beings struck or injured, if not killed; trees shivered, combustible bodies inflamed, metals melted, houses destroyed, during its mad and disastrous course—these are a few of the results of the thunderstorms of which, especially during the summer season, the papers yearly give accounts. On consideration, the above-mentioned effects are seen to be the same, on a larger scale, as those produced by the electric spark. The old-fashioned electric machines, which were looked upon as very wonderful before the discovery of the battery, but which are now relegated to the cabinets of the schools of natural philosophy, reproduced the phenomena of the thunderstorm. They can give a very long flash, which can melt and volatilize conductors of small sections—such as the silver of a looking-glass, or any other small metallic particles in its path. Later on, our powerful dynamo-electric machines have struck down men as victims to carelessness or accident. The thunderstorm, therefore, which takes its origin from at-

mospheric electricity, and the electric spark artificially produced by man, are in fact but one and the same thing; and, although other physicists had already divined this, it is, strictly speaking, to the genius of the immortal Franklin that we owe the practical demonstration of this fact. Guided by the theory previously emitted by him as to the power of points—that is to say, of the property which pointed metallic bodies possess of allowing electricity to escape through their sharpened extremities—he invented the lightning guard, which consists essentially in a pointed metallic rod, making perfect contact with the soil, placed on the object to be protected, the function of which was to dissipate continually the electricity of the earth. By this means, the *potential* (the difference of electrical level) of the clouds directly above the earth at that point is diminished, and therefore a discharge to earth rendered impossible. Even if the point were insufficient to this end, its beneficial action would make itself felt, since the lightning would strike it by preference, discharging itself directly to earth without injury to the neighbouring objects.

MODERN THEORIES RESPECTING LIGHTNING GUARDS.

The lightning protector, however, as conceived by its inventor, gives only relative safety, as many cases have occurred in which the discharge, although striking the point, has ramified to the internal or external metallic portions of the building; and this although the points were in perfect condition and in good contact with the earth. Researches on the cause

of this phenomenon led Melsens to devise, a few years ago, a special system of lightning conductor, which he put into execution for the first time for the purpose of protecting the Town Hall of Brussels.

According to Franklin, a good lightning conductor should consist in the erection of very high metallic rods with sharp points, and in good communication with the earth through a single conductor of large section. The higher the rod the greater would be the extent of buildings protected by the lightning conductor.

But it has now been demonstrated by distinguished physicists (among whom we may mention Professor Murani) that such a system of lightning conductors is insufficient, and gradually, but with certainty, modern ideas are displacing the mistaken notion of our forefathers.

As a matter of fact, the discharge which takes place between a cloud and a lightning guard may be considered as the discharge of a condenser, whose two coatings—cloud and earth—have opposite charges. The stratum of air lying between them presents, when compared with the enormous potentials brought into play, but little resistance, so that the discharge which takes place partakes always of an oscillating character, and, therefore, all those phenomena which depend upon high frequencies are verified—among which must be calculated that dependent on the impedance of the lightning conductor itself, which gives rise to a resistance which is incomparably greater than that of its calculated ohmic resistance. This impedance may become so great that the discharge cannot pass through the con-

ductor, or else in a very slight degree only, and along the outside of the conductor—the greater part passing along the surrounding di-electric, striking, as is often the case, the base of the lightning rod, or those portions of the buildings which lie round the rod itself.

The effects of the flash are therefore not so simple as our elementary books on physics would lead us to imagine, being much more complicated than was formerly believed, and accompanied by important secondary phenomena that certainly never entered the minds of the inventors of the lightning rod. These considerations lead us to understand how little importance can be placed on the statement that the zone protected by a lightning rod is in simple relation to the height of that rod; and we, therefore, must hold as destitute of any scientific foundation the empirical rules that are still in use, if we take into account that *impedance* may assume very high proportions.

Another consequence is that in calculating the conductance of a lightning rod, it is not the ohmic resistance that should be first taken into account, but its impedance $= \sqrt{R^2 + \left(\frac{2\pi L}{T}\right)^2}$, in which L stands for the co-efficient of self-induction; R the ohmic resistance; T the periodicity, which may be incalculably small. This can be reduced by making use of ribbon-shaped conductors, having a large surface, or else of a number of discharge wires stretched separately. Whatever be the system of lightning rod adopted, it is necessary that the communication between the points and the earth be perfect, as in a contrary case the lightning guard ... be the cause of serious disaster.

THE FRANKLINIAN SYSTEM.

Since the rod that bears the point must reach to a certain height, it is necessary in the first place that it should be sufficiently strong to stand the strain of gusts of wind, and have sufficient section not to be melted on the passage of the current set up by the lightning; secondly, in order to avoid expense, it must not be too heavy. To unite these two qualities, the rods are usually constructed of iron tubes, which, in addition, present the advantage of admitting of an interior discharge conductor. The diameter of the tube will vary with the height to which the rod is to be carried, those having a considerable height consisting of tubes of decreasing diameters joined together by stout brass collars with female screws, that present a facility in transport and in fitting that cannot be easily obtained otherwise.

In the annual inspection of the lightning conductors, and more especially of their points—which should never be neglected—this kind of rod is not without danger to the workman entrusted with the operation. He is often obliged to ascend a steep and narrow roof where he is compelled to risk his life on a small hand-ladder to reach the extremity of the rod, and it is to be regretted that several accidents have arisen from this cause. In order to render this inspection safer and less costly, a form of rod, shown in our Fig. 54, has been devised, and this is recommended for all important stations where lightning conductors are placed in positions difficult of access. By loosening a nut at the lower end of the rod, this latter may be inclined gently until its extremity be

FIG. 54.

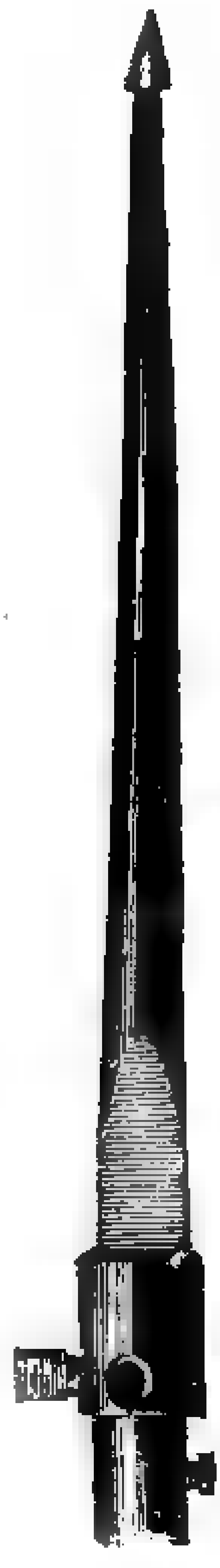

FIG. 55.

lowered to the level of the roof, and within reach of the operator. This rod at the upper end is fitted with a special device for supporting the points, that not only holds them firmly, but grips by means of a strong screw the end of the discharging conductor, so as to ensure perfect connection to the points. The conductor itself, passing in the interior of the supporting rod, comes out of a suitable aperture made in its base, and thence goes to earth. We shall not pause here to consider the matter of fastening the rod or tube to the roof—the usual plan is that of little brick pillars; but occasionally there is no convenience for building these, in which case saddles must be employed. Practice, and the necessities of the case, which may vary *ad infinitum*, can alone decide this point. Care, however, must be taken in any case, that the rod should be solidly fixed, in order that it should not swerve from its vertical position under the strain of violent winds or the weight of the enclosed conductor.

Generally speaking, lightning conductors are furnished at their base with a kind of inverted funnel, somewhat like a single-shed insulator, so that any rain-water running along the outside of the rod may be prevented from percolating into the roof.

Sometimes, although this is not to be recommended, the rods used in the protection of public buildings are fitted with pulleys which serve for raising flags or banners, in which case, the tubes must be of exceptional strength and supported by strainers in order that they may be able to bear the pull of the flags, especially during a hurricane. In this case, the points sometimes take the shape of a gilt mass, so

that the rod with its banner may present an artistic appearance. Usually, however, these points are constructed, as shown in our Fig. 55, of copper, this being the most suitable metal for the purpose, being an excellent conductor of electricity and of heat. In

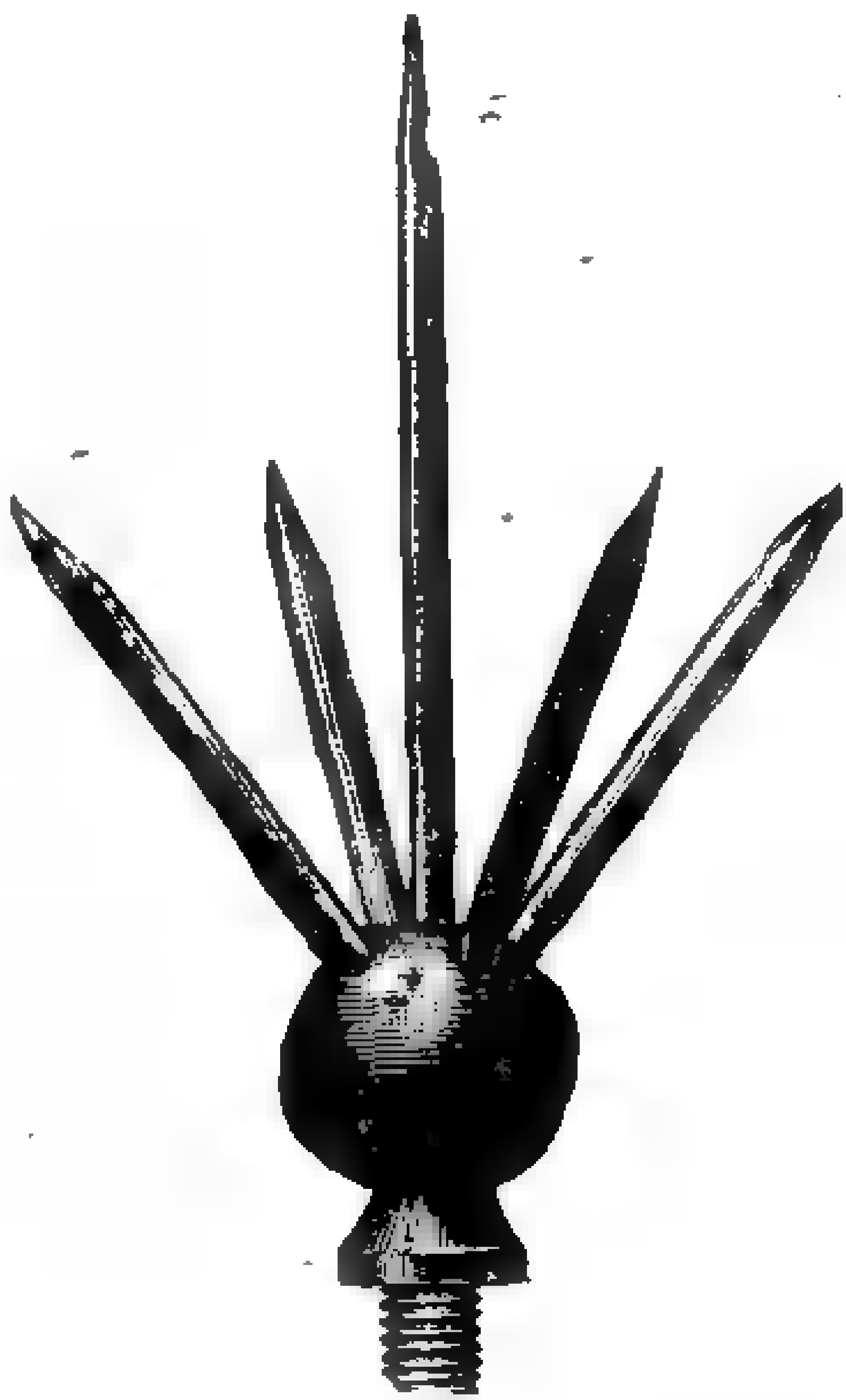

FIG. 56.

order to preserve the point from oxidation, it is fitted at its extremity with a sharp cusp of platinum.

Innumerable types of points are to be found in the trade, and there is not much choice in point of efficiency; but we recommend that preference should be given to the multiple points shown in our Figs. 56 and 57, which permit of a more rapid discharge of

the terrestrial electricity, and therefore ensure greater safety. The point should be fixed preferably at the northern extremity of the building.

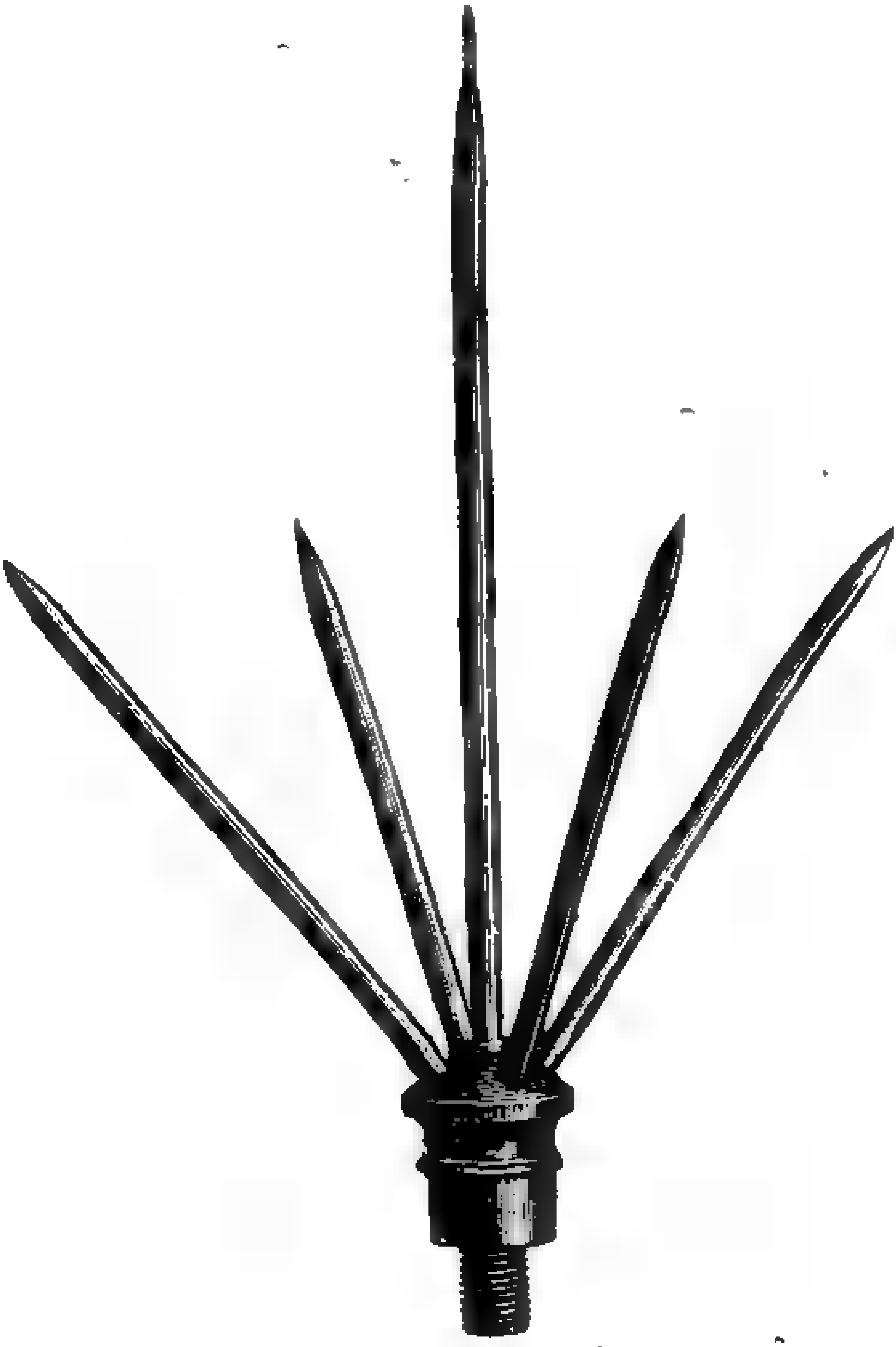

FIG. 57.

The discharging conductor generally takes the form of a metallic rope, usually of copper, that is

taken to the point or points at one end, and is connected at the other to a large sheet of copper that is buried in the ground. This is usually called the "earth" or "dispersing-plate," which, if possible, should be in the neighbourhood of wells or water-courses. In this latter case, care must be taken to tin all metallic portions that are plunged in water, partly to avoid the rusting of the copper, and partly to prevent the poisoning of the water with the verdigris. When natural streams of water or wells are not to hand, it will be necessary to sink one, selecting when possible damp situations, and providing by means of suitable drainage that rain-water should enter therein and maintain the humidity of the soil. Such excavations should be carried rather deep, especially if the soil be sandy or chalky, and should be situated at several yards from the buildings. In order to increase the surface of the contact between the plate and the earth a few tons of coke broken into small pieces should be rammed in. If charcoal is to be got, this would be found even better than coke for the purpose. The conductor, on its passage from the rod to earth, should be borne by several suitable iron supports, which must be insulated from it and from every other part of the building by special porcelain insulators.

The above is a brief account of the system adopted hitherto in the erection of lightning conductors; but this is rapidly giving way to that known as the Melsen System, also called the Multiple Point System. The system of Multiple Points, to which the studies of this Belgian scientist led him, and which was afterwards made public, along with the

logical arguments, was first taken up by N. Perrot, of Rouen, who showed the superiority of the system over every other form of lightning conductor. And, in fact, as may be now seen, Melsen's idea has been accepted favourably by both technical and scientific men.

On this system the rods are kept taut, but they are scattered in great number over the whole roof of the building. Naturally economy and theory will suggest the number and the position of the rods necessary to the protection of the edifice. The points must always be in large number, branched, and, preferably, from the economical point of view, made of galvanised iron, which, for this particular purpose, gives good results. On all metallic coverings or roofings, on the guttering for the rain-water, and on the supports of the main discharging conductor, are to be placed little protecting points of the design shown in Fig. 58, which are found to be of great assistance in the perfect working of the system.

The discharge conductor is not to be insulated on its way to earth; on the contrary, all the internal and external metallic portions of the building are to be connected up to the protecting system in such a manner as to form one complex whole. For this reason all the points, the water-courses, gutters, iron stanchions, metallic roofs, and the indoor gas and water pipes, are all to be connected up to the main discharge conductor.

These discharge conductors are to be in as great a number as possible, and arranged around the building to be protected in such a manner as to enclose it, as

it were, in a metallic cage; the greater their number the greater will be the safety ensured.

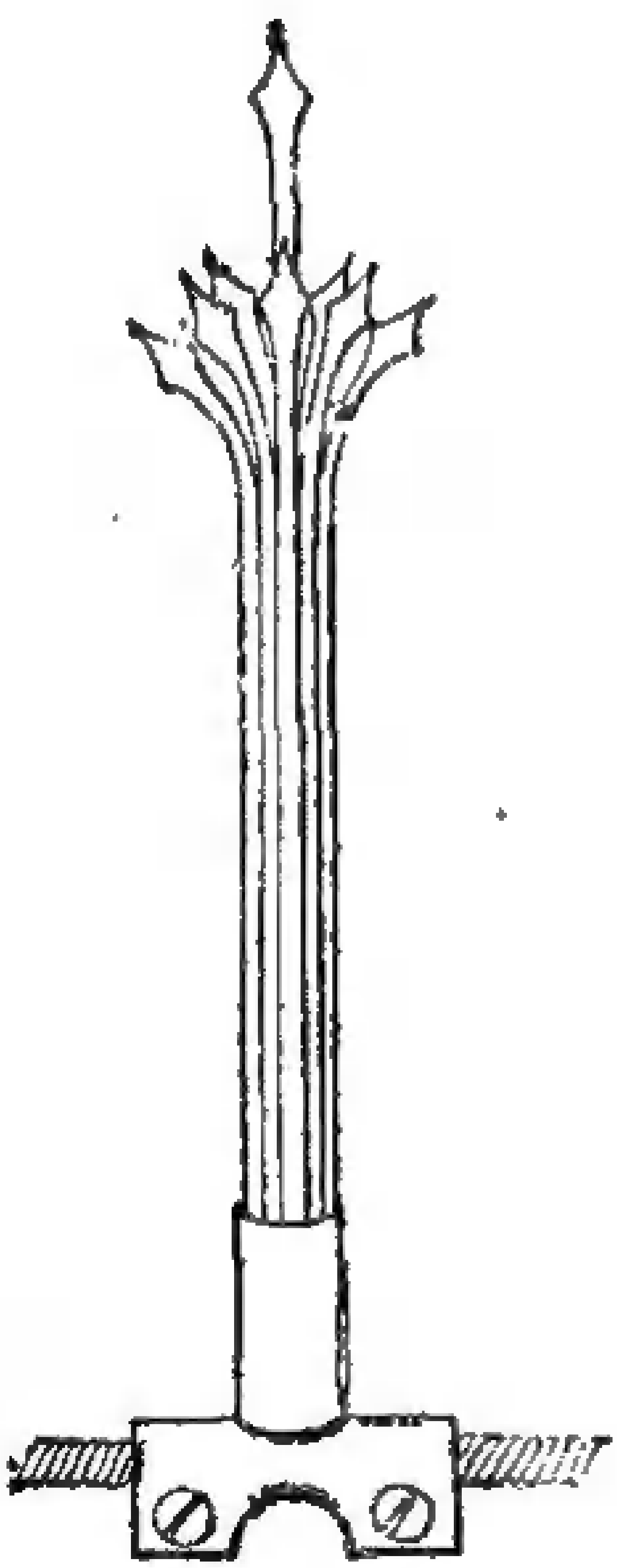

FIG. 58.

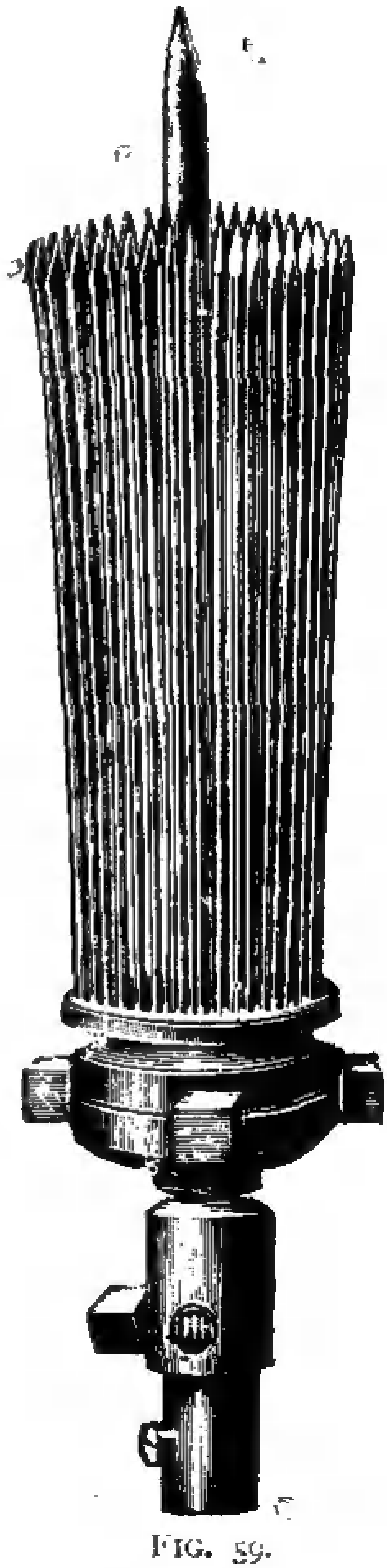

FIG. 59.

True wells or excavations for the current to dis-

charge itself into are not required; but all the conductors should be, however, united together by a metallic ribbon buried in the soil that surrounds the building.

One type of Multiple Point is that known as the "Crown," and this, both from its form and its arrangements, presents a large dispersion surface, so that if applied to the head or tip of the older lightning rods, it enables them to bear the most intense lightning flashes, if such should occur, which is most unlikely in view of the great neutralising power of the point thus modified. This particular arrangement (Fig. 59) is so constructed that it can be adapted to the pointed extremity of existing lightning rods without requiring the assistance of a skilled workman. It is sufficient to unscrew the four iron screws shown at the base of the "crown," and to slip this latter over the point of the said rod, allowing this to project somewhat above the level of the points of the crown, when the screws may be tightened up. The crown consists essentially in a stout bronze ring of about two inches in diameter, having a central aperture of one inch in diameter. Around this ring or collar are the four iron screws. In the upper face of this ring are inserted, parallel to its axis, forty small pointed copper rods, about six inches in length, and made lance-shaped where they are gilded. The simplicity of this apparatus enables the operator to modify, with little expense, lightning conductors made on the old style, and does not prevent the adoption of the modern improvements of connecting all the lower extremities of the conductors together, and thus ensuring the safety given by the latter systems.

INSPECTION OF LIGHTING CONDUCTORS.

This operation should never be neglected, but should be carried out at least once a year. The first thing to be ascertained is, whether the connection between the point—the discharging conductor and earth—be perfect. A trial of this is made by causing a weak current to pass through the entire system, by means of which, if there be any break or interruption at any point, it can be easily located.

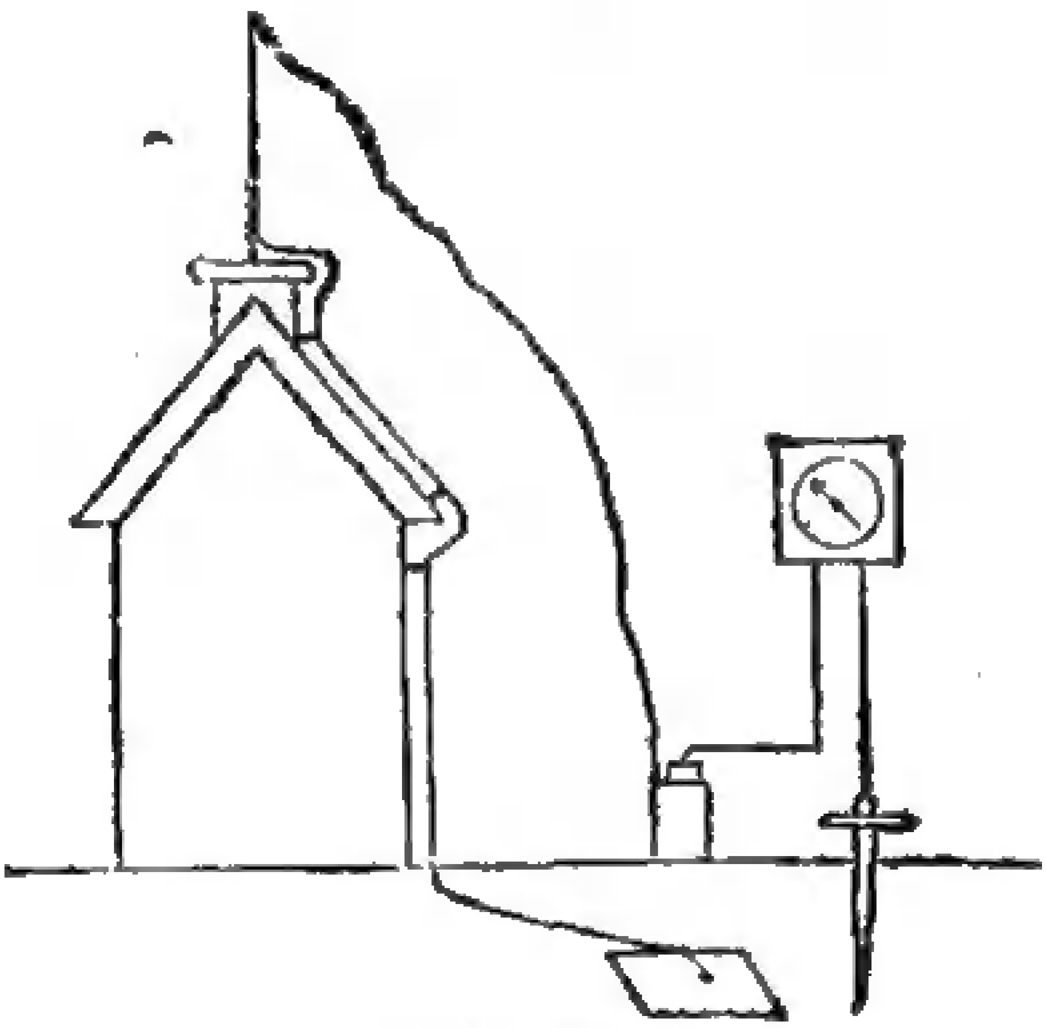

FIG. 60.

For the convenience of the workman, special portable boxes are constructed, containing all the apparatus necessary for the determination of the condition of the lightning conductor, conveniently arranged in circuit. This apparatus consists in a battery (usually made of dry cells, for convenience of carriage), a detector galvanometer to indicate the presence of the current, a hank of wire fitted with a special clip in order to enable one extremity to be

fastened to the tip of the conductor, and a piece of copper, which is to be buried in the ground in the neighbourhood of the excavation in which the earth-plate of the lightning conductor is plunged. By this means we have a complete metallic circuit to earth, around which will traverse, provided no defects exist, the current from the dry cell, and which will show itself more or less intensely on the galvanometer (see Fig. 60).

Of course, a preliminary trial must be made of the testing apparatus itself, which should give a fairly large deflection of the galvanometer needle. But should the lightning conductor on trial fail to allow any current to pass, or, in other words, should no indication of current be shown by the galvanometer, it will be easy, by sliding the jaws of the clip down the lightning rod, the conducting cord or cords, until the earth connection itself is reached, to locate precisely the point at which the defective connection is situated, when the connection should be immediately made good.

The amount of resistance presented by the conductor of the lightning rod (which, however, should always be kept as low as convenient) is of little or no importance, since, as we have already seen, its amount is always very trifling when compared with the inductive resistance or "impedance" set up by the oscillating nature of the lightning discharge. It is certainly interesting, from a scientific point of view, to measure or to calculate this impedance; but, from the practical side, little or nothing is to be gained by such measurements.